women, science, and technology

a reader in feminist science studies

edited by mary wyer, mary barbercheck, donna cookmeyer, hatice örün öztürk, and marta wayne

third edition

ROUTLEDGE

Women, Science, and Technology

Third Edition

Women, Science, and Technology is an ideal reader for courses in feminist science studies. The editors have extensively revised this anthology to reflect the newest trends in the field. The third edition contains emerging work in feminist science studies that focuses on specific scientific and technological research and calls attention to debates among feminists about how to envision our futures in relation to this research. *Women, Science, and Technology* continues to make the argument that scientific and technological advances are at once deeply implicated in the rigidity of the sex/gender classification system *and* necessarily useful to challenging that classification system. In addition, recent trends in theory motivate a rethinking of related systems of domination, including race/ethnicity, class, sexualities, and global relations. This new edition reflects those important developments as integral to feminist science studies while incorporating a international perspectives.

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A Reader in Feminist Science Studies

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Typeset in Utopia
by Apex CoVantage, LLC

We renew our dedication of this book to all those women in science and engineering who have been denied the good friendship and encouragement that have sustained us. Know that we are cheering for you all.

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PREFACE TO THE THIRD EDITION

As we began the work that launched the third edition of *Women, Science, and Technology* we confronted several challenges to continuing to provide an overview of feminist science studies for use inside and outside of the classroom. Selections in earlier editions were strategically chosen to make feminist perspectives on the sciences accessible to a general audience, to provide a framework that began with familiar themes from liberal feminist perspectives (describing unequal outcomes by gender and race/ethnicity, in education, employment, and training), then moved through the logic of cultural construction of scientific knowledge, ending with articles that pointed toward agency and action in shaping scientific and technological research agendas. It was a framework meant to persuade readers that feminist perspectives improved one's ability to critically examine the changes sweeping through our lives. In this new edition we advance from our previous focus to describe a new path forward as it reflects emerging work in feminist science studies that focuses on specific scientific and technological research, and it calls attention to debates among feminists about how to envision our futures in relation to this research. *Women, Science, and Technology,* in our selections, continues to make the argument that scientific and technological advances are at once deeply implicated in the rigidity of the sex/gender classification system *and* necessarily useful to challenging that classification system. In addition, recent trends in theory motivate a rethinking of related systems of domination, including race/ethnicity, class, sexualities, and global relations. This new edition reflects those important developments as integral to feminist science studies.

The 2013 edition of *Women, Science, and Technology* marks the fifteenth year since we began teaching our course, "Women and Gender in Science and Technology," at North Carolina State University, which sparked the development of the book. The first year we offered the course there were just five students enrolled, with all five of us teaching it. The course now routinely attracts more than 400 students a year and satisfies a university general education requirement at NC State, and it has been adopted widely throughout the United States. Our decisions about content for the new edition are in part due to the evolving interests and enthusiasms of students, who are more inclusive, global thinkers than their predecessors. What has become apparent to us in the past fifteen years is that our students are better educated about gender issues than they were when we began our work, that the topic of "feminist science studies" is not as scary to them as it once may have been, and that the topics that resonate most profoundly for them are related to the body. By "the body" we refer to women and men as embodied, laboring, thinking, breathing humans whose individual desires, dreams, and choices are contained by barely visible social, institutional, and economic boundaries. This third edition reflects this emphasis, around which there is lively debate within feminist theory, with articles that focus literally on the body as an object and subject of scientific and technological innovation as well as articles that engage the theoretical debates. Because of the increasingly specific level of terms and concepts that new scholars are bringing to feminist science studies, we trust that the third edition will challenge educators and students alike to talk across traditional disciplinary divides to embrace their inner feminist scientist.

In our hunt for new material and our review of the earlier introductions, we discovered several arenas in which significant change has taken place, and we want to mention these here—not to lay out a claim of discovering that all is well with the world, but rather to mark the moment and honor the change that has taken place. The arenas in which we note improvements, to name a few, are: the increasing representation of women as undergraduate and graduate degree earners in science, mathematics, and engineering; the increasing visibility of women's health care in public policy discussions; the increasing recognition that women scientists and engineers bring useful and (perhaps) distinct experiences to the table in the development, implementation, and adaptation of new discoveries; the increasingly institutionalized commitments of colleges and universities to denounce gender bias in education, employment, and training in science and engineering fields; and the decreasing representation of science and scientists as necessarily masculine (never mind engineering or computer science for the moment).

There is no shortage of heady concerns, however. Feminist theory is troubled by the analytic limitations of the sex/gender paradigm, the implications of recognizing that feminist lenses are as partial as those we critique, the increasing disconnect between research on issues related to exclusionary practices in STEM (science, technology, engineering, mathematics) fields and feminist science studies, the continuing lack of cross-talk between feminist science theorists and feminist scholars in traditional disciplines, and the need to enhance the level of scientific literacy within the ranks of women's and gender studies faculty. We leave to you the task of considering the possibilities of this dialog in light of your conversations around essays and themes herein. This book represents our effort to make a small wave in a sea of change.

In terms of professional changes, the five coeditors of this book have very different careers than those we held in the first edition, advancing through the academic ranks and no longer located at the same institution. We continue to bring divergent and specialized perspectives into our work together. Mary Wyer is now associate professor of psychology and women's and gender studies. She teaches theory and research on intersectionality, stereotypes, and feminist psychology. Her publications and empirical research program focus on how individuals' self-concept as scientists and attitudes toward equality in science influence career commitments and persistence in science, with attention to gender and race/ethnicity. Mary Barbercheck is a professor of entomology at Penn sylvania State University, with research and extension in sustainable agriculture. Her research focus is on soil ecology and the effects of management practices on insects and related organisms in organic cropping systems. Her interests in women and gender have expanded from STEM to include women in agriculture. These interests include conducting research with the

Pennsylvania Women's Agriculture Network, with a focus on improving agricultural production and marketing by women farmers in Pennsylvania and the northeastern United States. Donna Giesman Cookmeyer is now in research administration and is involved both in the oversight of clinical trials and institutional compliance. In her work she continues to rely on qualities central to the feminist scholarship on science, including issues of equity, equal participation, and transparency. Hatice Örün Öztürk divides her teaching time between biomedical engineering and electrical and computer engineering departments. She is the assessment and accreditation coordinator for the undergraduate programs in both departments. For the past four years she worked with the College of Engineering IT staff to implement a software program assessment tool designed under her leadership. She is an active member of the Women's and Gender Studies Program executive council and enjoys the increasing number of her engineering students taking the women and gender in science and technology course. Her first book of poetry is *Bread and Time* and was published in Turkish in 2012. Marta Wayne is now professor of biology and adjunct professor in the Center for Women's Studies and Gender Research at the University of Florida, teaching courses in genetics, genetical ethics, and science studies.

These differences in our professional pathways, particularly geographical distance, have made it logistically difficult to work together, but have also enriched our consideration of the field of articles from which we selected those included in the third edition. We all had to agree that articles spoke to issues of broad concern but in ways that were methodologically and theoretically sound. We decided to feature newer work, agreeing to set aside many articles that are old favorites and classics. We found consensus on the new directions of the work and then developed a narrative that provided coherence. The diversity of backgrounds and our divergent life experiences, shared in kitchen table discussions, proved to be indispensible in assembling the third edition. We hope you enjoy reading it as much as we enjoyed developing it.

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There are several people who have made it possible for us to sustain our work on *Women, Science, and Technology* by reminding us how important our work is and by assuming its merit. We give continuing thanks to the Women's and Gender Studies Program at NC State University; to colleagues in the NSF ADVANCE project (Laura Severin, Margaret Daub, Marcia Gumpertz, and Daniel Solomon); Banu Subramaniam for comments on early plans; the Department of Psychology at NC State; and the National Women's Studies Association Science and Technology Taskforce. All of you have sustained us along the way and often behind the scenes. We also thank Hilary Rampey for her careful, thoughtful, and precise marshalling of the project through every step as a research assistant extraordinaire. We would also like to thank our reviewers:

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INTRODUCTION: FEMINISM, SCIENCE AND TECHNOLOGY—WHY IT STILL MATTERS

This collection of writings is designed to engage the reader in the disorientations and diffractions (to borrow Donna Haraway's term) that constitute contemporary feminist science studies. The scholarship represented here begins with familiar feminist themes related to social biases that discourage the participation and advancement of women in science, technology, engineering, and mathematics (STEM), but this third edition of *Women, Science, and Technology* quickly moves into topics related to the content of the curriculum in higher education, critiques of prevailing knowledge about sex and gender, debates from within feminist science studies about the limits and possibilities of feminist theoretical perspectives, and envisioning of new futures unbounded by disciplinary prerogatives. Although it matters that women have been (and continue to be) systematically excluded from, or marginalized within, the intellectual machinery of scientific and technological development and innovation—and it especially matters to those who experience discrimination—this path of work is but a start to thinking about women, gender, science, and technology. The endpoint, for this edition, is to raise questions about what we are teaching in institutions of higher education, to whom, and for what purposes.

In an era in which conversations about diversity and inclusion have taken on national prominence in the United States, and the need to be globally competitive drives efforts to recruit talent to STEM careers, it may seem as if issues of inequality in STEM are passé. How could anyone still think that only white men are fit for STEM careers? The issues, unfortunately, are more complicated than simply recruiting more women and people of color into STEM fields—a *lot* more complicated, in substance, scope, detail, definitions, and debates. Feminist scholars have built an impressive body of theory and research that offers not only important additions and correctives to traditional disciplines but also new visions and insights that take decidedly interdisciplinary turns. Responding to Charlotte Bunch's famous warning that the new scholarship on women requires more than an effort to "add women and stir," feminist educators and researchers have quite literally built a new interdisciplinary field, women's and gender studies (Bunch 1987; Boxer 1998). According to the National Women's Studies Association, there are more than 700 women's studies programs in the United States alone, educating some 15,000 majors and minors (Reynolds, Shagle, and Venkataraman 2007). Thirty-two percent of these institutions offer graduate-level training as well.

At the same time, feminist scholars inside and outside of science and engineering disciplines have been at work developing new scholarship, research, and courses that bring feminist perspectives to a critical reappraisal of scientific knowledge long-assumed to be "objective" and "value-free" (Bleier 1984; Fausto-Sterling 1987, 1992; Harding 1991; Keller 1985, 1992; Longino 1990; Rosser 1997, Spanier 1995). The once controversial insight that knowledge is socially constructed—that human values and practices inevitably shape the knower, knowing, and known (Hawkesworth 1989)—now is less so, as the scientific community appears to acknowledge that some values, practices, and models of the natural world are more enduring and persuasive than others, that received "facts" emerge from consensus and debate, and that facts change over time even while interpretations of them reveal persisting ideologies (admirably argued by example in Richardson, herein; and by Fausto-Sterling [2000]). After all, humans cannot stand off-world, as claimed by the early Greek mathematician and engineer Archimedes, who is said to have (over)confidently asserted: "Give me a place to stand on, and I will move the earth." For instance, Western Enlightenment ideas about the "rational man" cast science as a practice designed to subdue Mother Nature, as represented by Francis Bacon's infamous metaphor, representing nature as a bride who must be subdued. "I am come in very truth leading to you Nature with all her children to bind her to your service and make her your slave" (Keller 1985, 33). Such language captures at once the systematic exclusion of women from scientific practice and a definition of masculinity that embraces objectivity as a quintessentially male mind state. Bacon's description of the relationship between scientists and nature also places scientists (men) in opposition to nature (women) and all too clearly indicates that nature must be controlled. Despite the value we continue to place in being objective and unbiased, science and engineering disciplines are nonetheless products of historical, cultural, and all-too-human invention. Institutions of higher education—their development, organization, practices, and underlying assumptions—have inherited the Enlightenment legacy of (white) male-as-objective, with troubling consequences (Minnich 2004; Flax 1987).

What precisely are the consequences? The list of systematic distortions, ignorance, and normalization of oppressive conditions is a long one. It includes the exclusion of most humanity from the knowledge-making enterprise by requiring a prolonged and expensive training period before one can be credentialed as a researcher; by concentrating decision making about the allocation of resources in the hands of a select few; by appropriating capital (intellectual and financial) from the public for investment in innovations that are exploited for profits, which are then diverted into corporate rather than public coffers; by the wholesale plunder of developing countries for resources to feed the innovation gods new capital investments; and by the appropriation of indigenous knowledge for exploitation by Western science. The liberatory potential of scientific research seems all but useless in the face of new waves of ignorance, misogyny, and violence against women globally and locally. Persisting and cruel inequality across the globe continues to deprive women of the means by which to secure food, shelter, safety, and an education for themselves and their children (Kristof and WuDunn 2009). In the United States many issues that would be resolved if women were recognized as fully entitled to constitutional protections continue to plague us. Debates about public funding of birth control, women's health services, and constitutional rights to privacy and same-sex marriage, for instance, continue to reveal deep societal ambivalences about whether women really ought to be full citizens with all the rights, privileges, and responsibilities of men. Even pay equity, which is widely supported, seems a distant dream.[1]

That these insults to women continue even in the face of important improvements is all the more maddening in light of a stubborn resistance to rationale, objective, and unbiased arguments among those who would use public policy to return women to second-class status.

Nonetheless, improving the educational, economic, and social status of all women is an enduring and keystone commitment of feminist scholarship and activism. There is perhaps no better example of this than the long and continuing struggle to ensure that women with the talent, ability, and interest to contribute to the world's scientific and technological advancement have the opportunity to do so. We have assembled this textbook in order to provoke our readers to envision a future in which scientists and engineers are actively engaged in challenging recalcitrant and calcified assumptions about nature, knowledge, sex, gender, and social change.

The feminist science scholars included in this edition of *Women, Science, and Technology,* represent five general approaches to building on, elaborating, and contributing to the foundations of feminist scholarship. These approaches include: (1) describing local and global inequities in access to education, training, and employment in STEM fields; (2) critiquing distortions and misrepresentations of women's minds and bodies in medical and scientific research and development (i.e., documenting and demonstrating the social construction of knowledge); (3) exploring technoscientific innovations as both colluding and colliding with the sex/gender/sexuality nexus; (4) reflecting on the limitations and possibilities of borderlands in feminist science theory; and (5) examining if/how prevailing paradigms (principally the nature/nurture dichotomy, but also male/female, human/animal, science/technology) direct or contain new insights. These five approaches, we propose, represent major currents in the most recent work in feminist science studies.[2]

1. Describing local and global inequities in access to education, training, and employment in STEM fields

In this approach, as captured by the readings in section 1, researchers have documented the continuing and newly emerging practices and processes that influence if, how, and how successfully women participate in scientific and technological initiatives. Although it is clear that biases continue to suppress, shape, and direct women's opportunities in STEM fields, the authors bring a wide variety of approaches to unveiling the ways in which biases operate and become evident. The experiment-based study report from Moss-Racusin et al., and an overview of data on women in academic science and engineering from Bilimoria and Liang, provide evidence that despite thirty years of dedicated effort, in the United States the proverbial pipeline continues to "leak" women, even at the highest levels and even with steady increases in women's participation. Sue Rosser points toward the patent process as a newly named barrier for advancement of women to the highest levels of influence, as women are less likely than men to convert their intellectual capital to a patentable innovation. Banu Subramaniam's classic fable "Snow Brown and the Seven Detergents" recounts how the "voluntary" erasure of cultural and gender markers is mandated in order to "fit into" the patriarchal culture of Western science. Marta Wayne uses an autobiographical approach to describe her move toward a feminist commitment in her scientific research after a series of bias-charged interactions with peers left her in doubt about her future. Ulf Mellström's study of computer science in Malaysia takes a multimethod approach to understanding how the social categories of Malaysian society (gender, class, race, age) interacted with nationalist development agendas to create a "situated body politics" that generated new economic opportunities for women. Londa Scheibinger and Martina Schraudner provide specific examples to illustrate how scientific research and innovation are distorted by the exclusion of women to make a case for re-educating STEM faculty and students about the consequences of the loss of talent from the creative process. As a whole, the section readings make the case for knowing the details, how/where the biases continue, how inequality affects individuals and structures social relations, how institutional practices support the persisting exclusion of women from positions of power and influence, and how all of this pushes us to think about what we teach, what we know, what we define as significant topics for future research.

Still, we are reminded by Jennifer S. Light's study of women programmers' contribution to the development of the first electronic computer in the 1940s that too little is changing too slowly. As one of these early contributors put it, to succeed one must "look like a girl, act like a lady, think like a man, and work like a dog." Arguably, especially in engineering disciplines where women remain dramatically underrepresented, this remains all too true today. Some would argue that this is further evidence of the continuing dominance of hegemonic masculinity in engineering, so that the best paying and most influential jobs in the global technoscientific economy remain in the hands of men (Cockburn 1985; Faulkner 2000).

2. Critiquing distortions and misrepresentations of women's minds and bodies in medical and scientific research and development (i.e., documenting the social construction of knowledge)

Section 2 is dedicated to providing exemplars of studies documenting the social construction of knowledge as evident in language, evolutionary theory, neurobiology, and the history, development, and use of technologies of the body. These articles argue for the importance of understanding the value of a feminist perspective to unraveling many of the most insidious elements of hegemonic masculinity—insidious because they are barely visible in a backdrop of claims to objectivity. Among the readings are two favorite classics from earlier editions of this textbook: Carol Cohn's groundbreaking (and still relevant) study of the language of defense intellectuals and Rachel Maine's history of the electromechanical vibrator as a socially camouflaged technology. Both articles raise provocative questions about how we "talk" about taboo topics and how language practices silence or mask discussion of topics critical to health and well-being. Two articles explore technologies related to menstruation, a quintessentially female biological process. Jennifer Aengst and Linda L. Layne detail and review debates about menstrual suppression as an "enhancement technology." Chikako Takeshita takes on the development and adoption of IUDs (intrauterine devices), providing a case study of a device that has many meanings, promoted by public health initiatives with purposes that range from providing new options for women to finding new ways to control women's choices. Both articles develop their arguments in the context of global perspectives and the diverse reproductive health needs of women.

In addition, readings in section 2 explore the consequences of unexamined, implicit, and problematic definitions of “nature” and “the natural” in relation to women’s bodies and minds. Erika Lorraine Milam’s essay follows a trail of shifting stereotypes through the development and application of evolutionary theory to understanding animal and human behavior, specifically sexual selection. Milam’s account is a compelling reminder of the ways in which theories are social constructs, that at any given historical moment a theory’s guiding concepts, misconceptions, insights, and underlying assumptions are deeply entangled with a host of debates about related questions; in this case, questions such as “What does it mean to be human?” “What is instinct?” “What distinguishes humans from (other) animals?” Rebecca M. Jordan-Young and Raffaella I. Rumiati bring this point home in their assessment of scientific research on the brain and sex differences. Their essay evaluates contemporary neurobiological evidence for the relevance of sex, sex differences, and sexuality in understanding the organization and function of the brain, much of it drawn from animal research. Like their trail blazing forerunner Ruth Bleier (1984), the authors demonstrate how assumptions about the significance of the two-sex system are reinscribed in research in neurobiology to reinforce the notion that there are stable and “natural” universal biological differences between women and men. As the authors point out, the practice of cataloging these differences is not an innocent one.

Deboleena Roy’s account of her efforts to escape the differences paradigm in her research on hormonal activity in the brain. Her article resonates with Marta Wayne’s account of becoming a feminist drosophila researcher from the first section, but Roy has elaborated her philosophical touchstones from recent feminist theory to posit premises for feminist practice in research in the natural sciences. Her approach includes, among other elements, an aversion to killing animals, which required her to challenge prevailing attitudes and practices but advanced her training and research productivity in keeping with her values. This is a hopeful essay, because it opens the door to feminist pathways to become and be a scientist.

3. Exploring technoscientific innovations as both colluding and colliding with the sex/gender/sexuality nexus

Readings in section 3 reflect feminist science studies scholars’ commitment to interrogating the notion that technoscientific advances emerge culture-free and have no intrinsic political or cultural meaning. We have brought these readings together in order to promote discussions about the extent to which investment of intellectual and social resources in these advances drives perpetuation of the binary sex/gender system. These essays provide specific instances in which ideas about sex and gender are, or are not, relevant to foundational knowledge about human biology, knowledge made possible by new technologies. The section launches with Ruth Hubbard’s effort to distinguish the ideological content of molecular genetics from the gender ideology that shaped the careers of two major contributors—Rosalind Franklin and Barbara McClintock. She contests the notion that women and men “do science” differently (i.e., x-ray diffraction techniques and microscopes are tools of the trade, no matter who uses them), making the point that there are irreducible facts to be uncovered and that one’s sex or gender has little to do with their validity or reliability.

Anne Fausto-Sterling’s essay similarly takes an empiricist stand but complicates the arguments considerably by proposing that “our bodies physically imbibe culture.” She points to research on human bone development that documents the ongoing influence of social determinants on global differences in bone health, including culturally distinct diets, exercise patterns, physical activities, drug use, aging patterns, and access to health care, among others. Fausto-Sterling posits a systems model for understanding bone development, a model that sees sex and gender as embedded elements of social determinants rather than biological ones.

Challenges to presuming that nature and culture exist as neatly distinguishable opposites continue in the next two articles, one by Rajani Bhatia and one by Dorothy E. Roberts. Bhatia tracks the commercialization and medicalization of reproduction, and the commodification of children, in the growth of sex-selection practices globally and in the United States. Her study provides a compelling example of the ways in which new reproductive technologies are disrupting taken-for-granted notions of who, how, and why people become parents, highlighting the "ability of humans to self-determine biologies and thereby identities, subjectivities, and destinies."

One particular innovation in reprogenetics, preimplantation genetic diagnosis (PGD), makes it possible to biopsy a single cell from early embryos, enabling physicians to screen for hundreds of genetic conditions while making decisions about which embryos to implant in assisted conceptions. Dorothy E. Roberts explores the legal, economic, and social implications of this technology, with attention to race, class, and gender inequalities. She raises an alarm about the growth of a global high-tech fertility industry that brings wealthy clients to tourist destinations in order to shop for the reproductive options they seek. This trend, she argues, does not erode race, class, and gender divisions; rather, it reinforces them by exploiting the notion that race categories are "natural" and "biological" and by appropriating the reproductive capacities of economically disadvantaged women of color to fulfill the parenting dreams of the world's wealthy.

The concluding article in this section recounts the intellectual history of research on the X chromosome. Sarah S. Richardson traces scientific and popular accounts of the X as the "female chromosome" from sex chromosome science in the early twentieth century through contemporary debates about X-mosaicism in autoimmune diseases among women. This is a fascinating account of the ways in which commitments to an ideology of sex differences has driven, distorted, and contained characterizations of the physiological functions on the X chromosome. Changes over time in these characterizations drew from whatever paternalistic, progressive, or misogynist stereotypes of women were in vogue. Richardson's study is a somber reminder that researchers who have no exposure to the critical and self-reflexive practices of feminist science are unlikely to escape the limitations of the intellectual legacy they inherit.

4. Reflecting on the limitations and possibilities of borderlands in feminist science theory

In section 4 authors reach out to feminist frameworks from a wide variety of (inter) disciplinary approaches—including cybermedia studies, material culture studies, queer studies, lesbian studies, labor studies, and postcolonial studies—to describe the current limitations of feminist science studies and to identify newly useful concepts and approaches. The essays touch on themes such as fostering dependence on Western technologies as if they were necessarily beneficial to humankind, the ways in which gender matters especially when women are erased from the calculation of who is human, the emergence of biotechnologies in global domination practices, and the importance of embracing "epistemological pluralism" as an unsettling but productive engagement with the complexities of building knowledge systems that are not Eurocentric or colonialist.

Jesse Daniels opens the section with an overview of cyberfeminist claims to the liberatory potential of digital technologies, describing the tensions between theorists who celebrate disembodied identities as escaping oppressive conditions and theorists who see cyberspace as a new platform for the reassertion of race, gender, and class power relations. Francesca Bray defines the overarching goal of feminist technology studies (as distinct from feminist science studies) as an effort to analyze how technologies are implicated in gender inequalities in order to work toward more democratic forms of technology, emphasizing the coproduction of technology with gender for specific innovations. Bray proposes that adoption of anthropological approaches to studying material culture, in particular the concept of sociotechnical systems, would enhance our ability to see how technologies travel with gender politics across time and space in systems that consolidate power and resist change. This approach shifts the topic from the characteristics of the innovation/gender relation to the processes by which some technologies, but not others, can (and perhaps do) disrupt oppression.

Catharina Landström's essay points out that feminist technology studies' commitment to the notion of technology and gender as coproduced implies that technology is "gender authentic" for men, and alien to women, using a "heterosexual matrix" as the normative framework for talking about technologies (Butler 1999). Landström outlines the possibilities for rethinking technologies from a queer theory perspective to disrupt and abandon the sex/gender binary as inadequate for understanding the full range of power relations that infect women's lives. Similarly, Petra Nordqvist reviews the specific case of reproductive technologies in relation to lesbian conception, noting the ways in which lesbians' use of reproductive technologies presents a challenge to the heteronormative undercurrents of feminist studies of infertility, conception, and reproduction.

The last two essays in this section, one by Catherine Waldby and Melinda Cooper, and the other by Sandra Harding, underscore the importance of transnational perspectives in theory and research on the global impacts of Western scientific and technological innovation. Waldby and Cooper tell a harrowing story about the emergence of a new and largely unregulated bioeconomy that appropriates tissue from women's bodies for stem cell research. We close with Harding's call for coalition between postcolonial and feminist science studies because she adeptly reminds us that although women face threats (global and local) to health and safety that we dared not imagine ten years ago, the best path forward may require us to engage with the uncertainty of it all.

5. Thinking about how prevailing paradigms (principally the nature/nurture dichotomy, but also male/female, human/animal, science/technology) can direct or contain new insights

Feminist science studies began as a critique of deeply flawed scientific claims to objectivity and a thorough examination of the social embeddedness of all knowledge-making activity. Trends in feminist theory in the past decade are reshaping feminist science studies, provoking efforts to develop critical, methodological, and thematic directions that take seriously the dismantling of the sex/gender system. There are several streams to these new directions, but they share a renewed commitment to building the kind of "better knowledge" that perhaps most feminists endorse; that is, one that is fully inclusive of women in all our global diversity, recognizes the multiplicity and simultaneity of social identities and sexualities, and envisions agentic and emerging social actors and selves in context. These new directions are unruly interdisciplinary forces that do not sit comfortably within traditional disciplines and can wreak havoc with conventional definitions of objectivity, detachment, and evidence. Psychology of gender, as one instance, is facing the troubling specter of complicity in generating catalogs of findings about gender differences that may be methodological artifacts (Crawford 2012; Magnusson and Marecek 2012; Shields 2008). Is there a *There* there if gender identities are emergent in social interaction? Are the tangible and material constraints faced by those who are systematically marginalized so inconstant and ephemeral that they escape patterned stabilities? As Donna Haraway puts it, our "problem is how to have *simultaneously* an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own 'semiotic technologies' for making meanings, *and* a no-nonsense commitment to faithful accounts of a 'real' world." Such a rethinking of prevailing paradigms of objectivity surely requires contesting (even abandoning) disciplinary boundaries.

The essays included in section 5 reflect the trends, directions, and challenges of such new directions in feminist science studies. Taken together, they evoke conversations about how to best represent the natural world and our active community investments in those representations—the priorities we set, questions we ask, language we use, standards of evidence we require, and the limitations of our analytic tools. The section ends the book with a hopeful essay by Niamh Moore, who reminds us that feminism has a long and enduring history of collective action, however fragmented or diffuse it may seem from time to time.

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On an ending note of collective action, then, this book stands as a call to action for rededication to curriculum transformation efforts that fully embrace feminist science and technology studies within and outside of women's and gender studies. One early premise in the push in the 1990s was that teaching "people-less" STEM courses suppressed or diverted the interests of everyone who valued STEM research and innovation as catalysts for improving human health and well-being (Musil 2001; Rosser 1995, 1997). This dynamic may be especially salient for women and people of color, who have been historically marginalized and excluded from education, research, and training in STEM fields. Research has demonstrated that including information about women and people of color in science classrooms improves students' knowledge about women's contributions in science and their assessment of the classroom climate (Damschen et al. 2005; Wyer et al. 2007). Energy for curriculum transformation has languished of late, and so we would like to posit a plan for steps in a national effort. First, we need to identify institutional partners and allies who have a commitment to the full participation of women and people of color in STEM. Second we need to develop a systematic process of transferring knowledge from feminist science and technology studies to other domains and departments (across the university). A third step, and one that is well underway, is to develop courses, curriculums, and concentrations that bring feminist science studies into routine interaction with STEM educators. A fourth step is to foster the conditions and climate that promote new research and knowledge within feminist science studies.

And the last (unapologetically empiricist) step is to explore and document the impacts that exposure to feminist science studies content has on student learning and interest in STEM fields. This is a worthy national project, one that provides a platform for more inclusive approaches to scientific and technological literacy and engagement. Our review of the literature, so necessary to assembling this textbook, reveals that we have a wealth of expertise, energy, and insight to offer higher education.

NOTES

1. See "The Campaign against Women," *New York Times,* May 19, 2012; "Women Buying Health Policies Pay a Penalty," *New York Times*, October 29, 2008; "Overhaul Will Lower Costs of Being a Woman," *New York Times*, March 29, 2010; "Virginia Lawmakers Vote against Women's Rights," *New York Times*, February 28, 2012; "Three Rulings against Women's Rights," *New York Times*, July 31, 2012; "Hey Baby! Women Speak Out against Street Harassment," CNN, October 6, 2012; "Male-female Pay Gap Persists and Starts Early," *New York Times,* October 24, 2012.
2. Subramaniam (2009) offers a thoughtful and useful overview that complements, but differs somewhat, from our characterization of the field.

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SECTION I

From Margins to Center: Educating Women for Scientific Careers

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CHAPTER 1

Science Faculty's Subtle Gender Biases Favor Male Students

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A 2012 report from the President's Council of Advisors on Science and Technology indicates that training scientists and engineers at current rates will result in a deficit of 1,000,000 workers to meet United States workforce demands over the next decade (1). To help close this formidable gap, the report calls for the increased training and retention of women, who are starkly underrepresented within many fields of science, especially among the professoriate (2–4). Although the proportion of science degrees granted to women has increased (5), there is a persistent disparity between the number of women receiving PhDs and those hired as junior faculty (1–4). This gap suggests that the problem will not resolve itself solely by more generations of women moving through the academic pipeline but that instead, women's advancement within academic science may be actively impeded.

With evidence suggesting that biological sex differences in inherent aptitude for math and science are small or nonexistent (6–8), the efforts of many researchers and academic leaders to identify causes of the science gender disparity have focused instead on the life choices that may compete with women's pursuit of the most demanding positions. Some research suggests that these lifestyle choices (whether free or constrained) likely contribute to the gender imbalance (9–11), but because the majority of these studies are correlational, whether lifestyle factors are solely or primarily responsible remains unclear. Still, some researchers have argued that women's preference for nonscience disciplines and their tendency to take on a disproportionate amount of child- and family-care are the primary causes of the gender disparity in science (9–11), and that it "is not caused by discrimination in these domains" (10). This assertion has received substantial attention and generated significant debate among the scientific community, leading some to conclude that gender discrimination indeed does not exist nor contribute to the gender disparity within academic science (e.g., refs. 12 and 13). Despite this controversy, experimental research testing for the presence and magnitude of gender discrimination in the biological and physical sciences has yet to be conducted. Although acknowledging that various lifestyle choices likely contribute to the gender imbalance in science (9–11), the present research is unique in investigating whether faculty gender bias exists within academic biological and physical sciences, and whether it might exert an independent effect on the gender disparity as students progress through the pipeline to careers in science. Specifically, the present experiment examined whether, given an equally qualified male and female student, science faculty members would show preferential evaluation and treatment of the male student to work in their laboratory. Although the correlational and related laboratory studies discussed below suggest that such bias is likely (contrary to previous arguments) (9–11), we know of no previous experiments that have tested for faculty bias against female students within academic science.

If faculty express gender biases, we are not suggesting that these biases are intentional or stem from a conscious desire to impede the progress of women in science. Past studies indicate that people's behavior is shaped by implicit or unintended biases, stemming from repeated exposure to pervasive cultural stereotypes (14) that portray women as less competent but simultaneously emphasize their warmth and likeability compared with men (15). Despite significant decreases in overt sexism over the last few decades (particularly among highly educated people) (16), these subtle gender biases are often still held by even the most egalitarian individuals (17), and are exhibited by both men and women (18). Given this body of work, we expected that female faculty would be just as likely as male faculty to express an unintended bias against female undergraduate science students. The fact that these prevalent biases often remain undetected highlights the need for an experimental investigation to determine whether they may be present within academic science and, if so, raise awareness of their potential impact.

Whether these gender biases operate in academic sciences remains an open question. On the one hand, although considerable research demonstrates gender bias in a variety of other domains (19–23), science faculty members may not exhibit this bias because they have been rigorously trained to be objective. On the other hand, research demonstrates that people who value their objectivity and fairness are paradoxically particularly likely to fall prey to biases, in part because they are not on guard against subtle bias (24, 25). Thus, by investigating whether science faculty exhibit a bias that could contribute to the gender disparity within the fields of science, technology, engineering, and mathematics (in which objectivity is emphasized), the current study addressed critical theoretical and practical gaps in that it provided an experimental test of faculty discrimination against female students within academic science.

A number of lines of research suggest that such discrimination is likely. Science is robustly male gender-typed (26, 27), resources are inequitably distributed among men and women in many academic science settings (28), some undergraduate women perceive unequal treatment of the genders within science fields (29), and nonexperimental evidence suggests that gender bias is present in other fields (19). Some experimental evidence suggests that even though evaluators report liking women more than men (15), they judge women as less competent than men even when they have identical backgrounds (20). However, these studies used undergraduate students as participants (rather than experienced faculty members), and focused on performance domains outside of academic science, such as completing perceptual tasks (21), writing nonscience articles (22), and being evaluated for a corporate managerial position (23).

Thus, whether aspiring women scientists encounter discrimination from faculty members remains unknown. The formative predoctoral years are a critical window, because students' experiences at this juncture shape both their beliefs about their own abilities and subsequent persistence in science (30, 31). Therefore, we selected this career stage as the focus of the present study because it represents an opportunity to address issues that manifest immediately and also resurface much later, potentially contributing to the persistent faculty gender disparity (32, 33).

CURRENT STUDY

In addition to determining whether faculty expressed a bias against female students, we also sought to identify the processes contributing to this bias. To do so, we investigated whether faculty members' perceptions of student competence would help to explain why they would be less likely to hire a female (relative to an identical male) student for a laboratory manager position. Additionally, we examined the role of faculty members' preexisting subtle bias against women. We reasoned that pervasive cultural messages regarding women's lack of competence in science could lead faculty members to hold gender-biased attitudes that might subtly affect their support for female (but not male) science students. These generalized, subtly biased attitudes toward women could impel faculty to judge equivalent students differently as a function of their gender.

The present study sought to test for differences in faculty perceptions and treatment of equally qualified men and women pursuing careers in science and, if such a bias were discovered, reveal its mechanisms and consequences within academic science. We focused on hiring for a laboratory manager position as the primary dependent variable of interest because it functions as a professional launching pad for subsequent opportunities. As secondary measures, which are related to hiring, we assessed: (i) perceived student competence; (ii) salary offers, which reflect the extent to which a student is valued for these competitive positions; and (iii) the extent to which the student was viewed as deserving of faculty mentoring.

Our hypotheses were that: Science faculty's perceptions and treatment of students would reveal a gender bias favoring male students in perceptions of competence and hireability, salary conferral, and willingness to mentor (hypothesis A); Faculty gender would not influence this gender bias (hypothesis B); Hiring discrimination against the female student would be mediated (i.e., explained) by faculty perceptions that a female student is less competent than an identical male student (hypothesis C); and Participants' preexisting subtle bias against women would moderate (i.e., impact) results, such that subtle bias against women would be negatively related to evaluations of the female student, but unrelated to evaluations of the male student (hypothesis D).

RESULTS

A broad, nationwide sample of biology, chemistry, and physics professors ($n = 127$) evaluated the application materials of an undergraduate science student who had ostensibly applied for a science laboratory manager position. All participants received the same materials, which were randomly assigned either the name of a male ($n = 63$) or a female ($n = 64$) student; student gender was thus the only variable that differed between conditions. Using previously validated scales, participants rated the student's competence and hireability, as well as the amount of salary and amount of mentoring they would offer the student. Faculty participants believed that their feedback would be shared with the student they had rated (see Materials and Methods for details).

Student Gender Differences

The competence, hireability, salary conferral, and mentoring scales were each submitted to a two (student gender; male, female) × two (faculty gender; male, female) between-subjects ANOVA. In each case, the effect of student gender was significant (all $P < 0.01$), whereas the effect of faculty participant gender and their interaction was not (all $P > 0.19$). Tests of simple effects (all $d > 0.60$) indicated that faculty participants viewed the female student as less competent [$t(125) = 3.89$, $P < 0.001$] and less hireable [$t(125) = 4.22$, $P < 0.001$] than the identical male student (Figure 1.1 and Table 1.1). Faculty participants also offered less career mentoring to the female student than to the male student [$t(125) = 3.77$, $P < 0.001$]. The mean starting salary offered the female student, $26,507.94, was significantly lower than that of $30,238.10 to the male student [$t(124) = 3.42$, $P < 0.01$] (Figure 1.2). These results support hypothesis A.

In support of hypothesis B, faculty gender did not affect bias (Table 1.1). Tests of simple effects (all $d < 0.33$) indicated that female faculty participants did not rate the female student as more competent [$t(62) = 0.06$, $P = 0.95$] or hireable [$t(62) = 0.41$, $P = 0.69$] than did male faculty. Female faculty also did not offer more mentoring [$t(62) = 0.29$, $P = 0.77$] or a higher salary [$t(61) = 1.14$, $P = 0.26$] to the female student than did their male colleagues. In addition, faculty participants' scientific field, age, and tenure status had no effect (all $P > 0.53$). Thus, the bias appears pervasive among faculty and is not limited to a certain demographic subgroup.

Mediation and Moderation Analyses

Thus far, we have considered the results for competence, hireability, salary conferral, and mentoring separately to demonstrate the converging results across these individual measures. However, composite indices of measures that converge on an underlying construct are more statistically reliable, stable, and resistant to error than are each

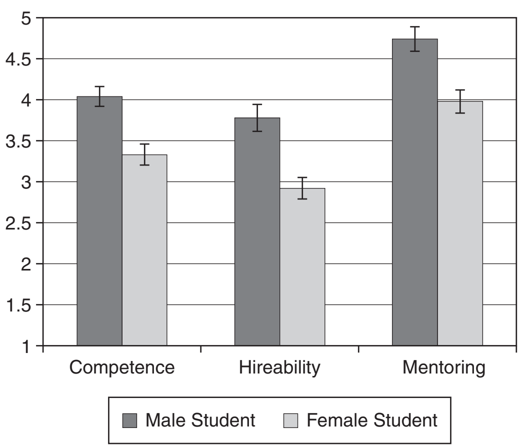

Figure 1.1 Competence, hireability, and mentoring by student gender condition (collapsed across faculty gender). All student gender differences are significant ($P < 0.001$). Scales range from 1 to 7, with higher numbers reflecting a greater extent of each variable. Error bars represent SEs. ^{n}male student condition = 63, ^{n}female student condition = 64.

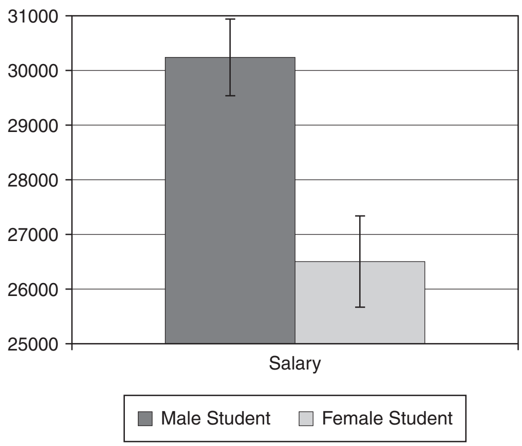

Figure 1.2 Salary conferral by student gender condition (collapsed across faculty gender). The student gender difference is significant ($P < 0.01$). The scale ranges from $15,000 to $50,000. Error bars represent SEs. ^{n}male student condition = 63, ^{n}female student condition = 64.

Table 1.1 Means for student competence, hireability, mentoring and salary conferral by student gender condition and faculty gender

	Male target student				Female target student				
	Male faculty		*Female faculty*		*Male faculty*		*Female faculty*		
Variable	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*d*
Competence	4.01^{a}	(0.92)	4.1^{a}	(1.19)	3.33^{b}	(1.07)	3.32^{b}	(1.10)	0.71
Hireability	3.74^{a}	(1.24)	3.92^{a}	(1.27)	2.96^{b}	(1.13)	2.84^{b}	(0.84)	0.75
Mentoring	4.74^{a}	(1.11)	4.73^{a}	(1.31)	4.00^{b}	(1.21)	3.91^{b}	(0.91)	0.67
Salary	30,520.83^{a}	(5,764.86)	29,333.33^{a}	(4,952.15)	27,111.11^{b}	(6,948.58)	25,000.00^{b}	(7,965.56)	0.60

Scales for competence, hireability, and mentoring range from 1 to 7, with higher numbers reflecting a greater extent of each variable. The scale for salary conferral ranges from \$15,000 to \$50,000. Means with different subscripts within each row differ significantly ($P < 0.05$). Effect sizes (Cohen's *d*) represent target student gender differences (no faculty gender differences were significant, all $P > 0.14$). Positive effect sizes favor male students. Conventional small, medium, and large effect sizes for *d* are 0.20, 0.50, and 0.80, respectively (51). ^{n}male student condition = 63, ^{n}female student condition = 64. ***$P < 0.001$.

of the individual items (e.g., refs. 34 and 35). Consistent with this logic, the established approach to measuring the broad concept of target competence typically used in this type of gender bias research is to standardize and average the competence scale items and the salary conferral variable to create one composite competence index, and to use this stable convergent measure for all analyses (e.g., refs. 36 and 37). Because this approach obscures mean salary differences between targets, we chose to present salary as a distinct dependent variable up to this point, to enable a direct test of the potential discrepancy in salary offered to the male and female student targets. However, to rigorously examine the processes underscoring faculty gender bias, we reverted to standard practices at this point by averaging the standardized salary variable with the competence scale items to create a robust composite competence variable ($\alpha = 0.86$). This composite competence variable was used in all subsequent mediation and moderation analyses.

Evidence emerged for hypothesis C, the predicted mediation (i.e., causal path; see SI Materials and Methods: Additional Analyses for more information on mediation and the results of additional mediation analyses). The initially significant impact of student gender on hireability ($\beta = -0.35$, $P < 0.001$) was reduced in magnitude and dropped to nonsignificance ($\beta = -0.10$, $P = 0.13$) after accounting for the impact of student composite competence (which was a strong predictor, $\beta = 0.69$, $P < 0.001$), Sobel's $Z = 3.94$, $P < 0.001$ (Figure 1.3). This pattern of results provides evidence for full mediation, indicating that the female student was less likely to be hired than the identical male because she was viewed as less competent overall.

We also conducted moderation analysis (i.e., testing for factors that could amplify or attenuate the demonstrated effect) to determine the impact of faculty participants'

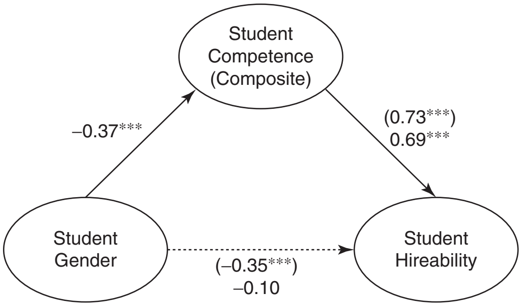

Figure 1.3 Student gender difference hiring mediation. Values are standardized regression coefficients. The value in parentheses reflects a bivariate analysis. The dashed line represents the mediated path. The composite student competence variable consists of the averaged standardized salary variable and the competence scale items. Student gender is coded such that male = 0, female = 1. ^{n}male student condition = 63, ^{n}female student condition = 64. ***$P < 0.001$

preexisting subtle bias against women on faculty participants' perceptions and treatment of male and female science students (see SI Materials and Methods: Additional Analyses for more information on and the results of additional moderation analyses). For this purpose, we administered the Modern Sexism Scale (38), a well-validated instrument frequently used for this purpose (SI Materials and Methods). Consistent with our intentions, this scale measures unintentional negativity toward women, as contrasted with a more blatant form of conscious hostility toward women. Results of multiple regression analyses indicated that participants' preexisting subtle bias against women significantly interacted with student gender to predict perceptions of student composite competence ($\beta = -0.39$, $P < 0.01$), hireability ($\beta = -0.31$, $P < 0.05$), and mentoring ($\beta = -0.55$, $P < 0.001$). To interpret these significant interactions, we examined the simple effects separately by student gender. Results revealed that the more preexisting subtle bias participants exhibited against women, the less composite competence ($\beta = -0.36$, $P < 0.01$) and hireability ($\beta = -0.39$, $P < 0.01$) they perceived in the female student, and the less mentoring ($\beta = -0.53$, $P < 0.001$) they were willing to offer her. In contrast, faculty participants' levels of preexisting subtle bias against women were unrelated to the perceptions of the male student's composite competence ($\beta = 0.16$, $P = 0.22$) and hireability ($\beta = 0.07$, $P = 0.59$), and the amount of mentoring ($\beta = 0.22$, $P = 0.09$) they were willing to offer him. [Although this effect is marginally significant, its direction suggests that faculty participants' preexisting subtle bias against women may actually have made them more inclined to mentor the male student relative to the female student (al-though this effect should be interpreted with caution because of its marginal significance).] Thus, it appears that faculty participants' preexisting subtle gender bias undermined support for the female student but was unrelated to perceptions and treatment of the male student. These findings support hypothesis D.

Finally, using a previously validated scale, we also measured how much faculty participants liked the student (see SI Materials and Methods). In keeping with a large body of literature (15), faculty participants reported liking the female (mean = 4.35, SD = 0.93) more than the male student [(mean = 3.91, SD = 0.1.08), $t(125) = -2.44$, $P < 0.05$]. However, consistent with this previous literature, liking the female student more than the male student did not translate into positive perceptions of her composite competence or material outcomes in the form of a job offer, an equitable salary, or valuable career mentoring. Moreover, only composite competence (and not likeability) helped to explain why the female student was less likely to be hired; in mediation analyses, student gender condition

($\beta = -0.48$, $P < 0.001$) remained a strong predictor of hireability along with likeability ($\beta = 0.60$, $P < 0.001$). These findings underscore the point that faculty participants did not exhibit outright hostility or dislike toward female students, but were instead affected by pervasive gender stereotypes, unintentionally downgrading the competence, hireability, salary, and mentoring of a female student compared with an identical male.

DISCUSSION

The present study is unique in investigating subtle gender bias on the part of faculty in the biological and physical sciences. It therefore informs the debate on possible causes of the gender disparity in academic science by providing unique experimental evidence that science faculty of both genders exhibit bias against female undergraduates. As a controlled experiment, it fills a critical gap in the existing literature, which consisted only of experiments in other domains (with undergraduate students as participants) and correlational data that could not conclusively rule out the influence of other variables.

Our results revealed that both male and female faculty judged a female student to be less competent and less worthy of being hired than an identical male student, and also offered her a smaller starting salary and less career mentoring. Although the differences in ratings may be perceived as modest, the effect sizes were all moderate to large ($d = 0.60$–0.75). Thus, the current results suggest that subtle gender bias is important to address because it could translate into large real-world disadvantages in the judgment and treatment of female science students (39). Moreover, our mediation findings shed light on the processes responsible for this bias, suggesting that the female student was less likely to be hired than the male student because she was perceived as less competent. Additionally, moderation results indicated that faculty participants' preexisting subtle bias against women undermined their perceptions and treatment of the female (but not the male) student, further suggesting that chronic subtle biases may harm women within academic science. Use of a randomized controlled design and established practices from audit study methodology support the ecological validity and educational implications of our findings (SI Materials and Methods).

It is noteworthy that female faculty members were just as likely as their male colleagues to favor the male student. The fact that faculty members' bias was independent of their gender, scientific discipline, age, and tenure status suggests that it is likely unintentional, generated from widespread cultural stereotypes rather than a conscious intention to harm women (17). Additionally, the fact that faculty participants reported liking the female more than the male student further underscores the point that our results likely do not reflect faculty members' overt hostility toward women. Instead, despite expressing warmth to-ward emerging female scientists, faculty members of both genders appear to be affected by enduring cultural stereotypes about women's lack of science competence that translate into biases in student evaluation and mentoring.

Our careful selection of expert participants revealed gender discrimination among existing science faculty members who interact with students on a regular basis (SI Materials and Methods: Subjects and Recruitment Strategy). This method allowed for a high degree of ecological validity and generalizability relative to an approach using nonexpert participants, such as other undergraduates or lay people unfamiliar with laboratory manager job requirements and academic science mentoring (i.e., the participants in much psychological research on gender discrimination).

The results presented here reinforce those of Stenpries, Anders, and Ritzke (40), the only other experiment we know of that recruited faculty participants. Because this previous experiment also indicated bias within academic science, its results raised serious concerns about the potential for faculty bias within the biological and physical sciences, casting further doubt on assertions(based on correlational data) that such biases do not exist (9–11). In the Steinpreis et al. experiment, psychologists were more likely to hire a psychology faculty job applicant when the applicant's curriculum vitae was assigned a male (rather than female) name (40). This previous work invited a study that would extend the finding to faculty in the biological and physical sciences and to reactions to undergraduates, whose competence was not already fairly established by accomplishments associated with the advanced career status of the faculty target group of the previous study. By providing this unique investigation of faculty bias against female students in biological and physical sciences, the present study extends past work to a critical early career stage, and to fields where women's underrepresentation remains stark (2–4).

Indeed, our findings raise concerns about the extent to which negative predoctoral experiences may shape women's subsequent decisions about persistence and career specialization. Following conventions established in classic experimental studies to create enough ambiguity to leave room for potentially biased responses (20, 23), the student applicants in the present research were described as qualified to succeed in academic science (i.e., having coauthored a publication after obtaining 2 years of research experience), but not irrefutably excellent. As such, they represented a majority of aspiring scientists, and were precisely the type of students most affected by faculty judgments and mentoring (see SI Materials and Methods for more discussion). Our results raise the possibility that not only do such women encounter biased judgments of their competence and hireability, but also receive less faculty encouragement and financial rewards than identical male counterparts. Because most students depend on feedback from their environments to calibrate their own worth (41), faculty's assessments of students' competence likely contribute to students' self-efficacy and goal setting as scientists, which may influence decisions much later in their careers. Likewise, inasmuch as the advice and mentoring that students receive affect their ambitions and choices, it is significant that the faculty in this study were less inclined to mentor women than men. This finding raises the possibility that women may opt out of academic science careers in part because of diminished competence judgments, rewards, and mentoring received in the early years of the careers. In sum, the predoctoral years represent a window during which students' experiences of faculty bias or encouragement are particularly likely to shape their persistence in academic science (30–33). Thus, the present study not only fills an important gap in the research literature, but also has critical implications for pressing social and educational issues associated with the gender disparity in science.

If women's decisions to leave science fields when or before they reach the faculty level are influenced by unequal treatment by undergraduate advisors, then existing efforts to create more flexible work settings (42) or increase women's identification with science (27) may not fully alleviate a critical underlying problem. Our results suggest that academic policies and mentoring interventions targeting undergraduate advisors could contribute to reducing the gender disparity. Future research should evaluate the efficacy of educating faculty and students about the existence and impact of bias within academia, an approach that has reduced racial bias among students (43). Educational efforts might address research on factors that attenuate gender bias in real-world settings, such as increasing women's self-monitoring (44). Our results also point to the importance of establishing objective, transparent student evaluation and admissions criteria to guard against observers' tendency to unintentionally use different standards when assessing women relative to men (45, 46). Without such actions, faculty bias against female undergraduates may continue to undermine meritocratic advancement, to the detriment of research and education.

CONCLUSIONS

The dearth of women within academic science reflects a significant wasted opportunity to benefit from the capabilities of our best potential scientists, whether male or female. Although women have begun to enter some science fields in greater numbers (5), their mere increased presence is not evidence of the absence of bias. Rather, some women may persist in academic science despite the damaging effects of unintended gender bias on the part of faculty. Similarly, it is not yet possible to conclude that the preferences for other fields and lifestyle choices (9–11) that lead many women to leave academic science (even after obtaining advanced degrees) are not themselves influenced by experiences of bias, at least to some degree. To the extent that faculty gender bias impedes women's full participation in science, it may undercut not only academic meritocracy, but also the expansion of the scientific workforce needed for the next decade's advancement of national competitiveness (1).

MATERIALS AND METHODS

Participants

We recruited faculty participants from Biology, Chemistry, and Physics departments at three public and three private large, geographically diverse research-intensive universities in the United States, strategically selected for their representative characteristics (see SI Materials and Methods for more information on department selection). The demographics of the 127 respondents corresponded to both the averages for the selected departments and faculty at all United States research-intensive institutions, meeting the criteria for generalizability even from nonrandom samples (see SI Materials and Methods for more information on recruitment strategy and participant characteristics). Indeed, we were particularly careful to obtain a sample representative of the underlying population, because many past studies have demonstrated that when this is the case, respondents and nonrespondents typically do not differ on demographic characteristics and responses to focal variables (47).

Additionally, in keeping with recommended practices, we conducted an a priori power analysis before beginning data collection to determine the optimal sample size needed to detect effects without biasing results toward obtaining significance (SI Materials and Methods: Subjects and Recruitment Strategy) (48). Thus, although our sample size may appear small to some readers, it is important to note that we obtained the necessary power and representativeness to generalize from our results while purposefully avoiding an unnecessarily large sample that could have biased our results toward a false-positive type I error (48).

Procedure

Participants were asked to provide feedback on the materials of an undergraduate science student who stated their intention to go on to graduate school, and who had recently applied for a science laboratory manager position. Of importance, participants believed they were evaluating a real student who would subsequently receive the faculty participants' ratings as feedback to help their career development (see SI Materials and Methods for more information, and for the full text of the cover story). Thus, the faculty participants' ratings were associated with definite consequences.

Following established practices, the laboratory manager application was designed to reflect high but slightly ambiguous competence, allowing for variability in participant responses (20, 23). In addition, a promising but still-nascent applicant is precisely the type of student whose persistence in academic science is most likely to be affected by faculty support or discouragement (30–33), rendering faculty reactions to such a student of particular interest for the present purposes. The materials were developed in consultation with a panel of academic science researchers (who had extensive experience hiring and supervising student research assistants) to ensure that they would be perceived as realistic (SI Materials and Methods). Results of a funneled debriefing (49) indicated that this was successful; no participant reported suspicions that the target was not an actual student who would receive their evaluation.

Participants were randomly assigned to one of two student gender conditions: application materials were attributed to either a male student (John, n = 63), or a female student (Jennifer, n = 64), two names that have been pretested as equivalent in likability and recognizeability (50). Thus, each participant saw only one set of materials, from either the male or female applicant (see SI Method and Materials for more information on all materials). Because all other information was held constant between conditions, any differences in participants' responses are attributable to the gender of the student. Using validated scales, participants rated student competence, their own likelihood of hiring the student, selected an annual starting salary for the student, indicated how much career mentoring they would provide to such a student, and completed the Modern Sexism Scale.

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CHAPTER 2

Snow Brown and the Seven Detergents

A Metanarrative on Science and the Scientific Method

Banu Subramaniam

Once upon a time, deep within a city in the Orient, lived a young girl called Snehalatha Bhrijbhushan. She spent her childhood merrily playing in the streets with her friends while her family and the neighbors looked on indulgently. “That girl, Sneha [as they called her], is going to become someone famous someday,” they would all say. Sneha soon became fascinated with the world of science. One day she announced, “I am going to sail across the blue oceans to become a scientist!”

There was silence in the room. “You can be a scientist here, you know.”

“But I want to explore the world,” said Sneha. “There is so much to see and learn.”

“Where is this place?” they asked.

“It’s called the Land of the Blue Devils.”

“But that is dangerous country,” they cried. “No one has ever been there and come back alive.”

“Yes, I know,” said Sneha. “But I have been reading about it. It is in the Land of the Kind and Gentle People. In any case, I can handle it.”

Her friends and family watched her animated face and knew that if anyone could do it, it would be brave Sneha, and so they relented. The city watched her set out and wished her a tearful farewell. She promised to return soon and bring back tales from lands afar. For forty-two days and nights Sneha sailed the oceans. Her face was aglow with excitement, and her eyes were filled the stars. “It’s going to be wonderful,” she told herself.

And so one fine day she arrived in the Land of the Blue Devils. She went in search of the Building of Scientific Truth. When she saw it, she held her breath. There it stood, tall and slender, almost touching the skies. Sneha shivered. “Don’t be silly,” she told herself. She entered the building. The floors were polished and gleaming white. It all looked so grand and yet so formidable. She was led into the office of the Supreme White Patriarch. The room was full. “Welcome, budding Patriarchs,” he said, “from those of us in the Department of the Pursuit of Scientific Truth. But let me be perfectly frank. These are going to be difficult years ahead. This is no place for the weak or the emotional or the fickle. You have to put in long, hard hours. If you think you cannot cut it, you should leave now. Let me introduce you to our evaluation system. Come with me.”

He led them across the hall into a huge room. At the end of the room stood a mirror, long and erect and oh so white. “This is the Room of Judgment,” he continued. “The mirror will tell you how you’re doing. Let me show you.” He went to the mirror and said, “Mirror, mirror on the wall, who is the fairest scientist of them all?”

"You are, O Supreme White Patriarch!" said the mirror.

The Patriarch laughed. "That is what all of you should aspire to. And one day when it calls out your name, you will take my place. But until then, you will all seek Truth and aspire to be number one. We want fighters here, Patriarchs with initiative and genius. And as for those who are consistently last in the class for six months . . . well, we believe they just do not have the ability to pursue Scientific Truth, and they will be expelled. Go forth, all ye budding Patriarchs, and find Scientific Truth."

Everyone went their way. Sneha found herself in the middle of the hallway all alone. "Go find Truth?" she said to herself. Was this a treasure hunt? Did Truth fall from the sky? She was very confused. This was not what she had thought it would be like. She went looking for her older colleagues. "Where does one find Scientific Truth?" she asked.

"Well," said he, "first you have to find the patronage of an Associate Patriarch or an Assistant Patriarch. You will have a year to do that. Until then, you take courses they teach you and you learn about Truths already known and how to find new Truths. During this time you have to learn how to be a scientist. That is very important, but don't worry, the mirror will assist you."

"How does the mirror work?" asked Sneha.

"Well, the mirror is the collective consciousness of all the Supreme White Patriarchs across the Land of the Kind and Gentle People. They have decided what it takes to be the ideal scientist, and it is what we all must dream of and aspire and work toward if we want to find Scientific Truth. You must check with the mirror as often as you can to monitor your progress."

Sneha tiptoed to the Room of Judgment, stood in front of the mirror, and said, "Mirror, mirror on the wall, who is the fairest scientist of them all?"

The mirror replied, "Not you, you're losing this game, you with the unpronounceable name!"

Sneha was very depressed. Things were not going as she had expected. "Oh, mirror," she cried, "everything has gone wrong. What do I do?"

"More than anything," said the mirror, "you have to learn to act like a scientist. That's your first task. Deep within the forests lives the Wise Matriarch in the House of the Seven Detergents. Go see her, she will help you."

Sneha set out to meet the Wise Matriarch. "Come in, child," she said. "What seems to be the problem?" She appeared to be a very kind woman, and Sneha poured out her misery.

"I know this is a very difficult time for you, but it is also a very important one," the Matriarch said.

"Why do they call you the Wise Matriarch?" Sneha inquired.

"I joined the Department of the Pursuit of Scientific Truth some twenty years ago," the Matriarch replied. "That is why I understand what you're going through. I was expelled. When the department offered me this position, I felt I could begin changing things. Over the years I have advised many budding Patriarchs. You could say I've earned my reputation.

"My child," she went on, "this is where the department sends its scientific misfits. Let me show you what they would like me to have you do." She led Sneha to a room, and in it stood seven jars. "These are the seven detergents," she said. "With them you can wash away any part of yourself you don't want. But the catch is that once you wash it away, you have lost it forever."

Sneha was excited. "First I'd like to get rid of my name and my accent. The mirror told me that."

The Wise Matriarch shook her head, "My child, do not give away your identity, your culture—they are part of you, of who you are," she cried.

"But," said Sneha, "I've always dreamed of being a scientist. I spent all my savings coming here, and I cannot go back a failure. This is truly what I want." Sneha got into the Great Washing Machine with the first detergent. *Rub-a-dub-a-dub, rub-a-dub-a-dub,* went the detergent.

"You may come out now, Snow Brown. Good luck."

Snow Brown went back amazed at how differently her tongue moved. For the next week she met the other budding Patriarchs, decided on her courses, and went out socializing with her colleagues. But everything was new in this land: how people ate and drank, even what people ate and drank. She felt stupid and ignorant. And just as she expected, when she went to the mirror, it told her that such behavior was quite unscientific and that she had to learn the right etiquette. Off she went again to the House of the Seven Detergents and used two other detergents that worked their miracles in the Great Washing Machine.

"Now I act like everyone else," she said, satisfied.

Snow Brown went to her classes. She thought them quite interesting. But the professors never looked her in the eye and never asked for her opinions. "Maybe they think I'm stupid," she said to herself. In class discussions everyone spoke up. Some of the things they said were pretty stupid, she thought. And so she would gather up her courage and contribute. She was met with stony silence. On some occasions others would make the same point, and the professor would acknowledge it and build on it.

She knew the mirror would be unhappy with her, and sure enough, she was right. "You have to be more aggressive," it said. "It doesn't matter so much what you say as how you say it."

"But that's ridiculous," she said. "Most of what is said is just plain dumb. Have you listened to some of them? They like the sound of their voices so much."

"That may be true, but that is the way. You have to make an impression, and sitting and listening like a lump of clay is not the way. And another thing—why did you let the others operate the machine in the lab? You have to take initiative."

"That was a ten-thousand-dollar machine. What if I broke it? I've never used it before." "Leave your Third World mentality behind. The Patriarchs see it as a lack of initiative.

They think you are not interested. You have to shoot for number one, be the very best. You have to act like a scientist, like a winner. Girl, what you need is a good dose of arrogance and ego."

Snow Brown was a little perturbed. She was disturbed by what she saw around her. Did she really want to act like some of the people she had met? What had happened to kindness, a little humility, helping each other? Just how badly did she want this, anyway? Her family was going to hate her when she went back. They would not recognize her. She thought long and hard and finally decided to go ahead.

She went back to the House of the Seven Detergents and used the anti-Third World detergent. When the Great Washing Machine was done, she came striding out, pride oozing out of every pore. The next day the Supreme White Patriarch called for her. "So, what kind of progress are you making in your search for Scientific Truth?" he asked.

"Well," she said, "the mirror has kept me occupied with learning to act like a scientist.

Surely you can't expect me to make as much progress as the others, considering."

"We don't like students making excuses, Snow Brown. You had better make some progress, and real soon. There is no place for laziness here."

Snow Brown started developing some of her ideas. She went to the mirror to talk them over.

"I'm thinking of working with mutualisms," she said. "Organisms associate with each others in numerous ways ecologically. They can both compete for the same resources as in competition. Some live off other organisms, and that's called parasitism. When organisms get into ecological relationships with each other that are mutually beneficial, it's called mutualism."

"To be frank, Snow Brown, I would recommend studying competition or parasitism." "But most of the studies of ecological interactions have focused on them," Snow Brown said. "I am amazed that there has been so little study of mutualisms. We know of some examples, but just how prevalent mutualisms are is still up in the air. For all we know, they may be a fundamental principle that describes demographic patterns of organisms on our planet."

"Whoa! Whoa!" cried the mirror. "You're getting carried away with your emotions. We would all like a and-they-lived-happily-ever-after kind of fairy tale. You are violating one of the fundamentals of doing science—objectivity. You don't pursue a study because you think it would be 'nice.' You base it on concrete facts, data. Then you apply the scientific method and investigate the problem."

"I do agree that the scientific method may have merit," she said. "I will use it to study mutualisms. But tell me, why do you think competition has been so well studied?"

"That's because competition is so important. Just look around you," the mirror replied.

"Are the Patriarchs working with each other for their mutual benefit, or are they competing?

This is what I do—promote competition. It is nature's way."

"Aha!" cried Snow Brown triumphantly. "You throw emotionalism and subjectivity at me. Listen to yourself. You are reading into nature what you see in yourself. I happen to believe that mutualisms are very important in the world. The Patriarchs have decided to work with a particular model. It doesn't mean that it's the only way."

"Get realistic," said the mirror, laughing. "You need the patronage of an Associate or Assistant Patriarch. You need to get money from the Supreme White Patriarch to do the research. Don't forget you need to please the Patriarch to get ahead. And you are still way behind in the game. This is not the time to get radical, and you are not the person to do it."

Convinced that pragmatism was the best course, the overconfident Snow Brown developed her ideas, talked in classes, and aggressively engaged the Patriarchs in dialogue. She was supremely happy. Things were finally going her way. She went to the mirror and said, "Mirror, mirror on the wall, who is the fairest scientist of them all?"

And the mirror replied, "It sure ain't you, Snow Brown. You're still the last one in town."

Snow Brown could not believe her ears. "I act and think like everyone around me. I am even obnoxious at times. What could I possibly still be doing wrong?"

"You're overdoing it," said the mirror. "You don't know everything. You should be a little more humble and subservient."

"Am I hearing things? I don't see anyone else doing that. This place does not validate that. You told me that yourself. What is really going on here?"

"When I advised you last," answered the mirror, "I advised you the way I would advise anyone, but I've been watching how the other Patriarchs interact with you. Apparently their expectations of you are different. You're brown, remember?"

Snow Brown was furious. She stormed out and went to the House of the Seven Detergents, and the sixth detergent washed her brownness away. She was now Snow White. She marched back to the Department of Scientific Truth. All the Patriarchs stared at her. They suddenly realized that what stood before them was a woman, and a beautiful one at that.

"Well, am I white enough for the lot of you now?" she demanded.

"Oh, but you're too pretty to be a scientist," cried the Supreme Patriarch.

"You can be a technician in my lab," said another.

"No, in mine!" urged yet another.

The Wise Matriarch had been right. Sneha had now lost her whole identity, and for what? Why had she not seen this coming? she asked herself. How could she ever have been the fairest scientist? How could she have been anything but last when judged by a mirror that wanted to produce clones of the Supreme White Patriarch? She went to the House of the Seven Detergents.

"It's too late, my child," said the Wise Matriarch. "You cannot go back now. I warned you about it. I wish I had more resources to support you and others like you. I have seen this happen far too often. It is important for you to communicate this to others. You must write down what has happened to you for future generations."

Two days later they discovered Sneha's cold body on the floor of her room. Her face looked tortured. In her sunken eyes was the resigned look of someone who had nothing more to lose to the world she had come to live in. On the nightstand by her body rested a tale entitled "Snow Brown and the Seven Detergents."

ENDING 1: AND INJUSTICE PREVAILS

The Patriarchs stood around the body. "It is so sad," said one. "But she was too emotional, a very fuzzy thinker. Some people are just not meant to pursue Scientific Truth. I wish they would accept it and leave instead of creating all this melodrama."

The other Patriarchs nodded in agreement at the unfortunate event.

"There is no reason for anyone to see this story, is there?" said the Patriarch who had initially spoken.

The others concurred, and they poured the last detergent on her. When they were done, there was nothing left. No pathetic face, no ugly reminders, no evidence.

ENDING 2: INTO EMPIRICISM

Snow Brown in her subversive wisdom sent copies of her story and insights to all in the department. There were some who kept the tale alive. It soon became apparent that there were dissenters within the Patriarchy. They broke their silence, and the movement slowly grew. Scientists began forming coalitions, talking and supporting each other in forming pockets of resistance. They questioned the power inequities. Why are most Patriarchs white? Why are most of them men? Over many decades the negotiations continued. Women scientists and scientists of color rose in the power structure. The collective consciousness was now male, female, and multicolored. But it was still supreme. It was privileged. The Pursuit for Truth continued, although new Truths emerged—Truths from the perspective of women, from the black, brown, yellow, red and the white. The world had become a better place.

ENDING 3: A POSTMODERN FANTASY

The story of Snow Brown spread like wildfire. The Land of the Blue Devils was ablaze with anger and rage. The Wise Matriarch and a number of budding Patriarchs stormed the Department of the Pursuit of Scientific Truth and took it over. The mirror was brought down. The Room of Judgment was transformed into the Room of Negotiation. In their first meeting after all this occurred, the scientists sat together. "We need a different model," they said. They dismantled the positions of the Supreme White Patriarch, the Emeritus Patriarch, the Associate Patriarch, the Assistant Patriarch, and the Young Patriarch. "We will be self-governing," they decided. They debunked the myth that truth was a monolithic entity. "Truth is a myth," they said. "One person's truth is often privileged over someone else's. This is dangerous. The Patriarchs privileged their worldview over all others. This distorts knowledge and makes an accurate description of the world impossible." Together they decided they could help each other in reconstructing science and rewriting scientific knowledge. The House of the Seven Detergents was dismantled, and the detergents were rendered invisible. The new Department of Scientific Endeavor was very productive. Its faculty and students solved many problems that had eluded the world for years. They became world renowned, and their model was adopted far and wide.

If you are ever in the forests in the Land of the Blue Devils and come across the voice of an old-school scientist arguing vociferously, you know you have stumbled across the ghosts of Snow Brown and the Seven Detergents.

CHAPTER 3

State of Knowledge about the Workforce Participation, Equity, and Inclusion of Women in Academic Science and Engineering

Diana Bilimoria and Xiangfen Liang

We include science, technology, engineering, and mathematics (STEM) fields as well as the social and behavioral sciences (SBS), under the overall rubric of science and engineering (S&E). The inclusion of women in S&E is directly connected to the future composition of the nation's S&E workforce and to the continued development of a globally competitive marketplace for talent.

THE PARTICIPATION OF WOMEN IN THE SCIENCE AND ENGINEERING WORKFORCE

In the past 20 years, the proportion of women and minorities in S&E occupations has increased considerably. As indicated in Figure 3.1, college-educated women constituted 27% of S&E occupation holders in 2007, up from 22% in 1990 (Science and Engineering Indicators 2010, Figure 3.27, pp. 3–32). The proportion of women with doctoral degrees in S&E occupations was 34% in 2007, up from 23% in 1990. Among workers whose highest degree is S&E bachelor's, the share of women has risen to above 60% in social sciences and life sciences in the recent cohort 2002–2005 (National Science Foundation 2010, Figure 3.29). Similarly, among workers whose highest degree is S&E doctorate, women also remained a higher percentage in the recent cohort (2002–2005), especially in social sciences (about 60%) and life sciences (about 45%) (National Science Foundation 2010, Figure 3.30).

In the STEM professional workforce, women were 19% of all managers and 15% of top-level managers in business or industry compared with 34% of all scientists and engineers in business or industry in 2006 (National Science Foundation 2009). They constituted 8% of engineering managers and 11% of natural sciences managers. Only in medical and health services were women more than half of managers (National Science Foundation 2009).

The workforce participation of women in the STEM professions is considerably larger at lower rungs in the corporate hierarchy–41% of qualified scientists, engineers, and technologists are women–yet, over time, 52% of these women quit their jobs, not in a steady trickle, but during their mid to late thirties (Hewlett, Luce, Servon, et al. 2008). These authors provide a fivefold explanation of this massive brain drain: hostile macho cultures, isolation from being the lone woman on a team or site, systems of reward that emphasize risk-taking, extreme work pressures, and lack of clarity about career paths (Hewlett, Luce, Servon et al. 2008).

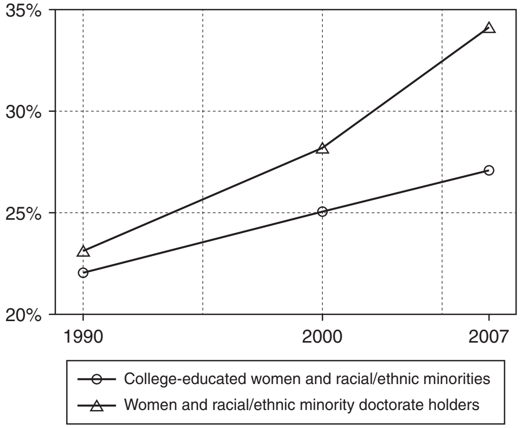

Figure 3.1 Women and racial/ethnic minorities with college or doctorate degrees in science and engineering occupations: 1990, 2000, 2007.

Source: Adapted from Figures 3–27 and 3–28, Science and Engineering Indicators 2010 (p.33), National Science Foundation.

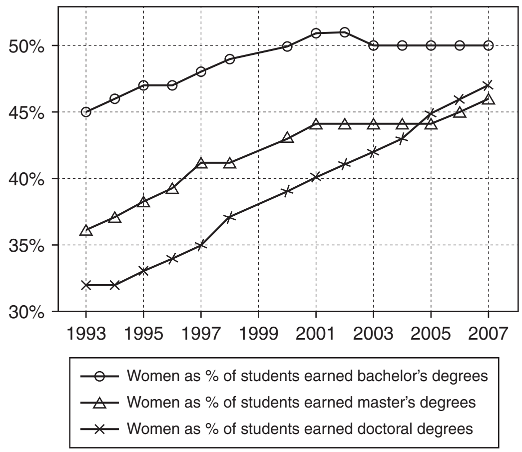

Figure 3.2 Women as a percentage of students by earned degree in S&E: 1993–2007.

Source: Data drawn from Appendix Tables 2–12, 2–26, 2–28, Science and Engineering Indicators 2010, National Science Foundation (www.nsf.gov.statistics/seind10).

THE PARTICIPATION OF WOMEN STUDENTS IN S&E FIELDS

Women also made considerable progress in obtaining S&E degrees over the years. Figure 3.2 presents the representation of women by earned degree from 1993 to 2007. In 2007, 485,772 students earned bachelor's degrees in the United States, and half of them (244,075) were women, up from 45% (165,720 out of 366,035) in 1993. Since 2000, half of the S&E bachelor degree's recipients have been women. At the graduate-school level, women students constituted 46% (54,925 out of 120, 278) of S&E master degree's recipients in 2007, up from 36% (30,971 out of 86,425) in 1993. The percentage of female students who earned S&E doctoral degrees also increased, up from 32% in 1993 to 47% in 2007.

According to Science and Engineering Indicators 2010 (National Science Foundation 2010), women earned 58% of all bachelor's degrees since 2002 and about half of all S&E bachelor's degrees since 2000, but major variations persist among fields. In 2007, men earned a majority of bachelor's degrees awarded in engineering, computer sciences, and physics (81%, 81%, and 79%, respectively) while women earned half or more of bachelor's degrees in psychology (77%), biological sciences (60%), social sciences (54%), agricultural sciences (50%), and chemistry (50%). Fields with marked increases in the proportion of bachelor's degrees awarded to women from 1993 to 2007 are earth, atmospheric, and ocean sciences (from 30% to 41%); agricultural sciences (from 37% to 50%); and chemistry (from 41% to 50%), However, women's share of bachelor's degrees in computer sciences, mathematics, and engineering has declined in recent years.

Women's participation in graduate S&E fields has also increased, Women made up 42% of S&E graduate students in 1993 and 50% in 2006, although large variations among fields persist. In 2006, women constituted the majority of graduate students in psychology (76%), medical/other life sciences (78%), biological sciences (56%), and social sciences (54%). They constituted close to half of graduate students in earth, atmospheric, and ocean sciences (47%) and agricultural sciences (48%) and more than one-third of graduate students in mathematics (37%), chemistry (40%), and astronomy (34%), Their percentages in computer sciences (25%), engineering (23%), and physics (20%) were low in 2006, although higher than in 1993 (23%, 15%, and 14%, respectively) (National Science Foundation 2010).

In 2009 women's share of engineering degrees hovered around 20% at all degree levels—17.8% of bachelor's degrees, 23% of master's degrees, and 21.2% of doctoral degrees. The percentage of women awarded doctoral degrees in engineering increased from 15.9% in 2000 to 21.2% in 2009 (Gibbons 2009). However, there is large variance by field: women's percentage of doctoral degrees varied from 12.6% in nuclear engineering to 37.7% in biomedical engineering (Gibbons 2009).

In brief, the number of female students and PhD recipients in S&E fields has been increasing in recent years. However, as the numbers presented in the next section show, these increases do not reflect corresponding increases in the number of female faculty in STEM areas, particularly at higher ranks, prompting many to refer to this phenomenon as a 'leaky pipeline' of faculty in these fields.

THE PARTICIPATION OF WOMEN FACULTY IN ACADEMIC S&E FIELDS

The job market of academic S&E disciplines has changed substantially in the past few decades. Full-time faculty positions have been declining, and postdoctoral and other full-time nonfaculty positions (e.g., research associates, adjunct appointments, and lecturers) have been increasing since the early 1970s (National Science Foundation 2010). The full-time faculty share of all academic employment was 72% in 2006, down from 88% in the early 1970s; the full-time nonfaculty share rose from 6% in 1973 to 13% in 2006; and postdocorates rose from 4% in 1973 to 9% of all academically employed S&E doctorate holders in 2006 (Science and Engineering Indicators 2010, Table 5.6, pp. 5–20). Along with these movements, women have gained an increasing share of the academic workforce composition. In 2006, 33% of all S&E doctorate holders employed in academia were women, up from 9% in 1973 (Science and Engineering Indicators 2010, Table 5.9, pp. 5–22). Women doctorate holders constituted more than half of part-time positions in academic S&E during 1993 and 2006.

In academic S&E fields, women hold a larger share of junior faculty positions than senior positions. In 2006, women constituted 25% of full-time senior faculty (full and associate professors) and 42% of full-time junior faculty (assistant professors and lecturers). Despite these gains, women are significantly more likely to hold nontenure-track positions (30% of full-time women faculty compared to 18% of men), are appointed to tenure track positions in most fields in far lower proportions than their representation in the candidate pool of doctoral degrees granted in the last decade, and are less likely to be tenured faculty than men, especially in doctoral institutions where "full-time women faculty are only half as likely as men to have tenure" (West & Curtis 2006, 10). Importantly, the percentage of women with S&E doctorates (including social and behavioral sciences) who are full-time full professors increased from 14% in 1999 to 20.6% in 2008; however, the percentage of under-represented minority S&E doctorate holders in full professor positions remained relatively flat, from 4.5% in 1999 to 5.7% in 2008 (National Science Foundation 2011).

Figure 3.3 shows the relative status of women doctorate holders by academic positions held. Overall, women doctorate

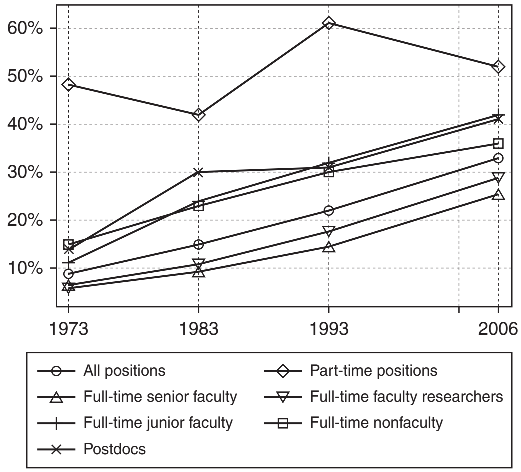

Figure 3.3 Women as a percentage of S&E doctorate holders by position in academic employment: selected years, 1973–2006.

Source: Drawn from Tables 5–9, p. 5–22, Science and Engineering Indicators 2010, National Science Foundation.

Notes: Academic employment limited to U.S. doctorate holders employed at 2- or 4-year colleges or universities. Senior faculty includes professors and associate professors. Junior faculty includes assistant professors and instructors. Full-time non-faculty includes positions such as research associates, adjunct positions, lecturers, and administrative positions. Part-time employment excludes those employed part-time because they are students or retired.

holders have made encouraging progress in occupying academic positions but they are under-represented at senior faculty positions, and moderately represented at the junior faculty positions.

Analyses of the workforce participation of women faculty reveal under representation in several STEM fields. Leboy (2008) noted that since close to half of the top ten National Institutes of Health–funded academic health centers in 2006 had no women among their junior tenure-track faculty in their biochemistry and cell biology departments, a young woman might get the impression that her shot at a faculty position in these schools would be difficult, if not out of reach. In schools of engineering, women constituted 12.7% of the tenured or tenure-track faculty in 2009 (up from 10.4% in 2004)—21.6% of assistant professors (17.9% in 2004), 14.5% of associate professors (12.4% in 2004), and 7.7% of full professors (5.8% in 2004) (Gibbons 2009). By field, the percentage of women tenured or tenure-track faculty in 2009 varied from 6% in mining engineering to 22.1% in environmental engineering (Gibbons 2009).

Academic chemistry exhibits very similar patterns of the underrepresentation of women, even though relatively more women complete doctoral degrees in chemistry. In 2003–2004, women held only 12% of all tenure-track faculty positions and only 21% of assistant professor positions at the top 50 chemistry departments (Nolan, Buckner, Kuck, & Marzabadi 2004). The American Chemical Society reported that the percentages of full-time, female, doctorate faculty members at PhD-granting universities, master's granting institutions, baccalaureate institutions, and two-year colleges were 13%, 20%, 26%, and 32%, respectively (Nolan et al. 2004).

The estimated total number of full-time faculty in mathematical sciences for 2004–2005 was 20,224, of which 5,302 (26%) were females (Kirkman, Maxwell, & Rose 2005). The number of females as a percentage of full-time faculty varied considerably among the groups in 2004, from 12% for doctoral-granting departments in private institutions to 32% for master's-granting departments. In fall 2004, the percentage of women in mathematical sciences was generally higher in statistics (26%) than in the doctoral mathematics groups (18%). Similarly, the percentage of tenured faculty who are women was highest in departments granting either a master's or a baccalaureate degree only (21%), and lowest in doctoral-granting departments (9%). Women in mathematical sciences accounted for 52% of non-doctoral full-time faculty, and 4%

of the part-time faculty in 2004. The percentage of tenured/tenure-track women faculty in mathematical sciences over the period 1998–2004 remained relatively stable (Kirkman et al. 2005).

Among S&E doctorate holders with academic faculty positions in four-year colleges and universities, females are less likely than males to be found in the full professor positions and more likely to be assistant professors (National Science Foundation 2011). This is consistent with findings from Nelson (2007), who examined the percentage of male and female tenured and tenure-track faculty in several disciplines, including S&E, at the top 50 U.S. educational institutions, based on research expenditures: few female full professors in S&E with the percentage of women among full professors ranging from 3% to 15% in different fields. Nelson (2007) also noted that in all but computer science, the rank of assistant professor has the highest percentage of female faculty. In converse, the rank which has highest percentage of male faculty is typically that of full professor, and that is the rank held by the majority of male faculty as well. Fewer differences in rank exist between male and female faculty in early-career stages in S&E, but greater differences tend to appear between 15 and 20 years after receipt of the doctorate.

Research also indicates that women are underrepresented in senior academic ranks and faculty leadership positions such as presidents, chancellors, provosts, deans, and chairs (Hollenshead 2003). This may be related to the difficulties women faculty in STEM face in academic career advancement (e.g., due to gender stereotyping and lack of mentoring) and the fact that they may not obtain the same levels of professional recognition for their scholarly work as do their male colleagues. In a comprehensive study of almost 60,000 faculty members at 403 academic institutions, Astin and Cress (2003) reported that male faculty attained tenure in a shorter amount of time than female faculty in all fields, with the exception of engineering. Other research has shown that women are less likely than men to receive tenure or promotion in STEM fields (Rosser & Daniels 2004). It has also been pointed out that the gender gap in compensation may be due in part to gender differences in rank, field (Astin and Cress 2003), and promotions (National Science Foundation 2003). As Astin and Cress (2003, 58) note, “At research universities, 25% of men are in the more highly paid fields of physical science, mathematics/statistics, and engineering combined, compared to 6% of women. Likewise, more than twice as many women (33%) as men (16%) are in the less financially lucrative fields of education, health science and humanities combined.”

EDUCATIONAL ATTAINMENT AND WORKFORCE PARTICIPATION OF MINORITIES IN ACADEMIC S&E

Underrepresented minorities (blacks, Hispanics, and American Indians/Alaska Natives as a group) and Asians/Pacific Islanders earned 17.4% and 8.7% of S&E bachelor’s degrees in 2008, up from 15.9% and 8.2% in 2000 (National Science Foundation 2011). Underrepresented minorities (URMs) earned 7.2% of S&E doctorates to U.S. citizens and permanent residents in 2008, up from 6% in 2000, while Asians/Pacific Islanders earned 5.8% of S&E doctorates in 2009, down from 6.2% in 2000. URM and Asian shares of S&E bachelor’s and doctoral degrees have risen slightly or flattened over the last decade; more importantly, they remain a small proportion of the total (National Science Foundation 2011). Underrepresented minorities constituted 10% of all scientists and engineers in business or industry in 2006, 7% of top-level managers, and 6%–13% of managers in most S&E fields (National Science Foundation 2009).

The data regarding URM faculty in S&E are also disturbingly low. The 2010 report *A National Analysis of Minorities in Science and Engineering Faculties at Research Universities,* a comprehensive demographic analysis of tenured and tenure track faculty in the top 100 departments of science and engineering disciplines, shows that minorities are significantly underrepresented in the academic S&E pipeline (Nelson & Brammer 2010). The report concludes, "Our data reveal that URMs among our science and engineering faculty are shockingly underrepresented despite increased general growth in their representation among B.S. and Ph.D. recipients. As expected, compared to their share of the U.S. population, URMs are underrepresented at almost every point in the academic pipeline. In most disciplines, there is a drop in representation at each point measured, with a gradual decrease up to the rank of 'full' professor, where the lowest representation is found; this reflects an increase in recent hiring in those disciplines. However, in some disciplines, the representation of Blacks, Hispanics, or Native Americans, among assistant professors (the most recently hired rank) is lowest and occasionally zero" (Nelson & Brammer 2010, 18). These data provide evidence that the academic pipeline is leaky for racial/ethnic minority faculty as well.

The case of Asian Americans in academic S&E careers is a particular problem of underrepresentation (Chen & Farr 2007). While Asian Americans are a population minority (about 5%) in the United States, they are overrepresented among students and professionals in S&E, holding more than 15% of all S&E doctoral degrees (National Science Foundation 2003). As faculty at many research universities, Asian Americans are not considered to be underrepresented; rather, they constitute minorities who are not underrepresented. The *glass ceiling* is a concept reflecting the workplace barriers to workforce participation and advancement facing specific minority groups. Chen and Farr (2007) delineate four criteria for a glass ceiling: (a) the inequality represents a demographic difference (e.g., gender or race/ethnicity) that is not explained by other job-relevant characteristics of an employee (e.g., education, training, discipline, location), (b) the inequality is greater at higher levels, (c) the inequality is one of opportunity and not merely an inequality in proportions of people at high levels, and (d) the inequality increases over the trajectory of a career. These authors analyzed data over the period 1993–1999 and found the existence of a glass-ceiling effect for Asian Americans (both men and women) at all stages of their S&E careers, and confirmed the effect for all women (regardless of race) in S&E (Chen & Farr 2007). Xie and Shauman (2003) found that women immigrant scientists are more severely disadvantaged than native-born women scientists in employment and advancement, unlike male immigrant scientists in comparison with their native-born counterparts; this gender difference was attributed to differences in the migration paths taken by men and women—men scientists more likely to be primary immigrants and women scientists more likely to be secondary immigrants.

In summary, multiple sources and historical data reveal the long-standing and consistent underrepresentation of women in S&E fields. Most problematic is the low proportion of women faculty at higher levels in the academic hierarchy.

UNDERREPRESENTATION AND INDIVIDUAL DIFFERENCE EXPLANATIONS

The concept of *underrepresentation* is itself subject to multiple interpretations

(Stewart, Malley, & LaVaque-Manty 2007). Underrepresentation may mean that women should participate in every activity in society in rough proportion to their numbers in the population (about half), or it may mean that women should be expected to participate on university faculties in rough proportion to their attainment of doctoral-level degrees. Underrepresentation may occur in terms of many dimensions such as tenure status, rank or position, and leadership opportunities (Stewart et al. 2007).

Two concepts illustrate various dynamics of underrepresentation: token or solo status, and critical mass. The literature on *tokens or solos*—individuals who are the sole representatives of their group (e.g., by race, gender, rank, or tenure status)—suggests that they are perceived and treated differently than others in a work setting (Kanter 1977; Yoder & Sinnett 1985; Yoder 1991; Niemann & Dovidio 1998). Solos are more likely to be subject to stereotyping, scrutiny, and negative judgment (Thompson & Sekaquaptewa 2002), and experience greater internal stress (Bilimoria & Stewart 2009). When individuals constitute a "significant minority" and not tokens, they begin to be viewed through more individualistic and less stereotyped lenses. The phenomenon of solo and minority women faculty in academic STEM departments is widespread, especially in top research universities.

A second related concept is that of *critical mass*. The theory of critical mass suggests that a meaningful representation of women in a group facilitates their individual differentiation (thereby helping them evade token treatments, reduce performance pressures, and escape role entrapment) and increases the possibility of their forming alliances and coalitions to alter the prevailing culture (Kanter 1977). Critical mass is linked to positive educational and career outcomes. For example, Latinos/Latinas student success was found to be higher at community colleges in which they constitute more than half of students and more than a third of the faculty (Hagedorn, Chi, Cepeda, & McLain 2007). Defining critical mass departments as those with more than 15% women faculty and departments with token status as having less than 15% women faculty, Etzkowitz, Kemelgor and Uzzi (2000) found that women faculty in critical mass departments reported relationships with significantly higher levels of social support and identity enhancement, more network contacts, and more reciprocation from network contacts as compared with women faculty in departments with token status.

Similar to the definition of a critical mass of students as defined by the American Educational Research Association, Elam, Stratton, Hafferty, and Haidet (2009) suggested that a critical mass of faculty may be defined as a contextual benchmark that allows an institution to exceed token numbers within its faculty body and to promote the robust exchange of ideas and views that is central to an institution's mission. Etzkowitz, Kemelgor, Neuschatz, Uzzi, and Alonzo (1994) identified a strong minority of at least 15% as necessary fulcrum to move toward critical mass. While the specific operational definition and the contextual benchmark of a critical mass of women faculty in academic S&E is yet to be specified (Elam et al. 2009), in the field of corporate governance it has been empirically determined that while a lone woman can and often does make substantial contributions and two women are generally more powerful than one, in a small-group setting such as a corporate board it takes three or more women to achieve a critical mass that can cause a fundamental change in deliberation processes and enhance corporate governance (Kramer, Konrad, & Erkut 2006; see also Erkut, Kramer, & Konrad 2008). This study found that having a critical mass of women directors is good for corporate governance in at least three ways: different views and perspectives of multiple stakeholders are likely to be considered, difficult issues and problems are considerably less likely to be ignored or brushed aside, and discussions are more open and collaborative.

Varied explanations have been offered for the continued underrepresentation of women and girls in science and engineering fields, constituting a "culture-to-biology spectrum" (Ceci & Williams 2007, 20). At the biological-differences end of the spectrum is the proposition that girls have lower cognitive skills (specifically, certain mathematical and spatial rotation abilities) than do boys—and that these nuanced deficiencies ultimately lower women's chances of success at ensuing stages of their academic S&E careers. While specific sex-based cognitive skill differences have been cited by some to explain the low proportions of women and girls in scientific and engineering research careers (see Ceci, Williams, & Barnett 2009), it is beyond the scope of the current study and the present review to deeply delve into some of the highly nuanced merits of such arguments; we focus instead on the institutional level cultural and structural causes of women's underrepresentation and the institutional remedies that more readily yield possibilities of improvement in women's workforce participation, equity, and inclusion. Nevertheless, we acknowledge here, then Harvard University president Lawrence Summer's 2005 citation of possible innate gender differences at the extreme right end of the distribution of mathematical and spatial cognition abilities (coupled with a dismissal of rival socialization, stereotyping and unconscious bias, and institutional-barriers explanations) as sparking considerable interest and debate over the biological causes of women's underrepresentation in science.

Many have strongly refuted cognitive-difference explanations for the dearth of women in S&E on the following grounds. First, girls' scores in mathematics achievements in other countries refute arguments about the possible innate nature of observable differences in the U.S.—girls in Japan and Singapore outperform boys in the U.S. on math tests, to the extent that "The cross-national differences dwarf the sex differences" (Valian 2007, 29). Second, U.S. girls have considerably improved their scores on mathematics measures as well as their performance in undergraduate and graduate STEM fields over the past decades, indicating that the gap is not immobile (e.g., Xie & Shauman 2003). The American Association of University Women's 2010 report *Why So Few? Women in Science, Technology, Engineering and Mathematics* provides a summary of evidence that recent gains in girls' mathematical achievement demonstrate the importance of culture and learning environments in the cultivation of abilities and interests (Hill, Corbett, & St. Rose 2010). As this report states, "Thirty years ago there were 13 boys for every girl who scored above 700 on the SAT math exam at age 13; today that ratio has shrunk to about 3:1. This increase in the number of girls identified as 'mathematically gifted' suggests that education can and does make a difference at the highest levels of mathematical achievement" (Hill, Corbett, & St. Rose 2010, xiv). Third, it appears that specific kinds of spatial cognition training can elevate girls' (and boys') spatial skills (Newcombe 2007), and both test scores and career choices can be positively influenced by removal of internalized stereotypes and biases. Believing in the potential for intellectual growth, in and of itself, improves test scores and intentions to pursue STEM careers; internalized negative stereotypes about girls' and women's STEM abilities can be overcome by improving the classroom environment and individual training (Steele & Aronson 1995; Spencer, Steele, & Quinn 1999; Nguyen & Ryan 2008; see also Dweck 2007, 2008).

Other individual level differences may contribute to women's employment decisions and success, particularly their demonstration of psychosocial abilities such as self-confidence, political skills, and propensity to engage in negotiations, as compared with men's. A recent study of more than 1,300 intramural postdoctoral researchers at the National Institutes of Health documents a self-confidence gap (in the expectations of success) between women and men postdoctoral researchers (Martinez et al. 2007). This survey found that women are more likely to quit at the postdoctoral researcher to principal investigator (PI) transition on account of two reasons: (a) family responsibilities—spending time with family, plans to have children, affordable child care, travel, and proximity to spouse's workplace were some of the considerations that were weighed more heavily by women, whereas salary was more important to men, and (b) self-confidence—although men and women rated themselves equally when it came to professional skill, men were significantly more confident that they could obtain a PI position and become tenured than were women (Martinez et al. 2007). The causes of women's less optimistic outlook about their future success as PIs were not examined in this study. Rather, the investigators urged future research to examine "whether this lower confidence originates from foreseen future challenges that affect women more than men—such as child-bearing, child care, and/or a less favorable professional environment—or whether they indicate that women underestimate their professional ability" (Martinez et al. 2007). An interview-based study of 31 women engineers found that "persistent" women engineers (those who stayed in the engineering workforce for an average of 21 years) versus those who opted out (those who left the engineering workforce after an average of 12 years) demonstrated more self-efficacy in dealing with work-related issues, were more other-oriented, were more likely to adapt to the masculine engineering culture, were more engaged in engineering-related learning and professional growth, and perceived themselves as having alignment between their personal and career aspirations (Buse, Perelli, & Bilimoria 2010). In another study of 3,700 women engineering-degree holders, Fouad and Singh (2011) found that women engineers who were more self-confident in their abilities to navigate their organization's political landscape and juggle multiple life roles reported being highly satisfied with their jobs as well as their careers.

Political skills involve an individual's behaviors to gain information regarding formal and informal work relationships and power structures within an organization (Chao, O'Leary-Kelly, Wolf, Klein, & Gardner 1994). They reflect the ability to get things done by understanding and working through others outside of formally prescribed organizational mechanisms (Ferris, Davidson, & Perrewé 2005). Higher levels of political knowledge and influence behaviors are associated with increases in annual salaries (Judge & Bretz 1994) and supervisor ratings of job performance (Ferris et al. 2005). However, women are less likely than men to engage in or use organizational politics, possibly due to a perception of incompetence, lack of confidence, and distaste for political activity, preferring to rely instead on formal mechanisms of influence, sometimes at the cost of career progression (Arroba & James 1988; Mann 1995). Similarly, sex differences in the propensity to negotiate have been employed to explain various career outcomes (e.g., Babcock & Laschever 2003; Babcock, Gelfand, Small, & Stayn 2006). However, while women may be less likely to engage in negotiation behaviors, there may be good reasons for this—recent research has documented that women face social sanctions (such as be disliked or perceived as demanding) and be penalized for initiating negotiations (Bowles, Babcock, & Lai 2007).

INSTITUTIONAL EXPLANATIONS OF WOMEN'S UNDERREPRESENTATION: THE LEAKY PIPELINE

Focusing exclusively on programs to remedy gaps in individual skill differences has had limited success in unlocking S&E educational pathways and improving S&E workforce participation for women; instead, a more systemic approach is needed (National Academies 2003; Rosser 2004; National Academies 2007a). A singular emphasis on individual-level explanations to rectify extant underrepresentation and inequities overlooks powerful workplace dynamics that constrain women's participation and success. For example, in the same study of 3,700 women engineering-degree holders mentioned above (Fouad & Singh 2011), perceptions of the engineering workplace climate were critical in their decisions to not enter or leave the engineering profession. Of those women who chose not to enter the engineering profession after college, a third indicated it was because of their perceptions of engineering as being inflexible or the engineering work place culture as being nonsupportive of women. Of those women who left engineering, almost half said they left engineering because of working conditions, too much travel, lack of advancement or low salary, and one-third said they left because they did not like the workplace climate, their boss, or the culture (Fouad & Singh 2011).

Individual skill-based differences such as those cited in the section above lend themselves to recommendations for specific training and development to better equip women to more successfully navigate for success in their workplaces and careers. Exclusively relying on such support interventions has been sometimes referred to as *fix the woman* or *women's problems* or *band-aid* approaches, and "have been characterized as efforts that focus on a 'deficit' model, in which it is assumed that these individuals lack something—ability, experience, interest, inspiration, motivation—that they need in order to succeed" (Muller 2003, 122–123). Although these approaches do not systematically address root causes, they support and encourage individual girls and women, and as such have a role to play in a comprehensive institutional strategy for remedying workplace underrepresentation and inequities, and may also catalyze longer-term shifts in institutional culture (Muller 2003).

Going behind the numbers and outcomes of underrepresentation is important (Long 2001). Attention only to aggregate growth trends in workforce participation masks several aspects of the demographics of the S&E workforce (Rosser & Taylor 2009). First, it masks a decrease over recent decades in white U.S. men, the traditional group from which the U.S. has drawn its STEM workforce. Second, the aggregated data also hide the wide variance in women's participation in specific fields. Women earn most of the bachelor's degrees in non-STEM fields and men earn most of the degrees in STEM (e.g., computer sciences, physical sciences, and engineering). Third, aggregated data mask the attrition of women at every phase of the educational and career STEM pipeline. More women than men leave S&E, even though their grades or academic attainments are equivalent.

The leaky pipeline has been used to describe this steady attrition of girls and women along the educational and academic career pathway. Academic career development can be conceptualized as a pipeline which carries women students from secondary school through higher education

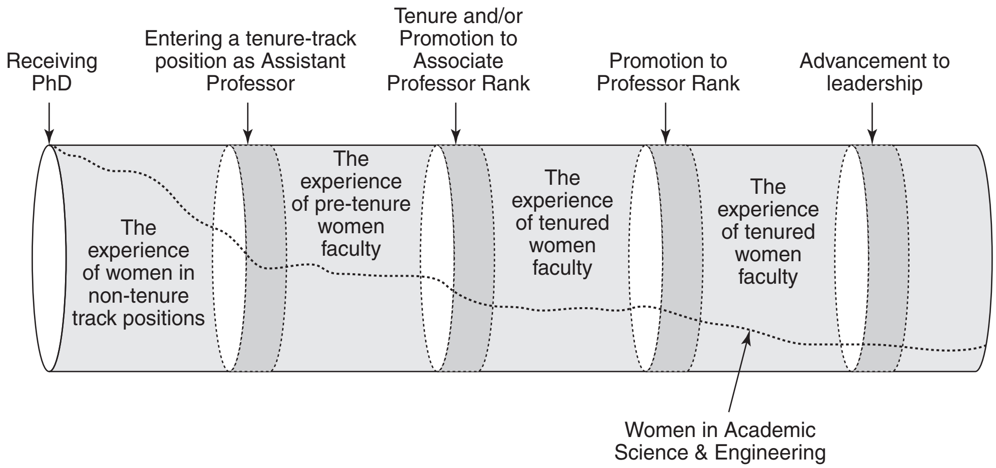

Figure 3.4 Pictorial representation of the leaky pipeline for woman in academic Science and Engineering.

and on to a faculty job and beyond. At each transition point in the academic pipeline, however, a lower proportion of women advance to the next milestone than their male colleagues, compelling many to refer to this pathway as a 'leaky pipeline' since it loses women at every step. As illustrated in Figure 3.4, the leaky pipeline is metaphorically used to describe the loss of women faculty at each transition point. This figure illustrates the steady attrition of women at successive stages in the educational and career pipeline.

Of course the metaphor of the leaky pipeline is not without criticism. For example, Herzig (2004) notes that the pipeline metaphor poses students as passive participants in their education, whose progress through their education is affected only by market forces. Further, a leaky pipeline does not adequately address why students of some demographic groups stay in STEM while others leave in greater proportions, and it fails to model important features of postsecondary STEM education that may contribute to attrition, such as its competitive and individualistic nature (Herzig 2004). Some, such as Mattis (2007, 336), propose a pathway rather than a pipeline since the former "connotes flexibility and freedom of movement, whereas pipeline brings to mind a mechanical and constrained course of action." Xie and Shauman (2003, 209) propose a life-course perspective, providing evidence that "in contrast to the rigid 'leaking only' career path dictated by the pipeline metaphor, career processes are fluid and dynamic, with exit, entry, and reentry all being real possibilities at any point in a career." Despite these and other critiques, the pipeline continues to be the prevailing reality in academic careers, and the leaky pipeline persists as a widespread and powerful symbolic representation of the problematic issues surrounding the workforce participation of women in academic STEM.

Below we describe relevant systemic—cultural and structural—challenges and barriers facing women S&E faculty as they progress through each major career stage in the academic pipeline. For each transition point, we describe the main causes of the leakages (challenges and barriers) as well as the experiences of women while they are at that stage.

Pipeline Leaks Prior to the Tenure Track

Barriers to Entering the Tenure Track Facing Women PhD Holders

Sufficient numbers of female doctoral graduates are generally present in the disciplinary recruitment pools for S&E faculty (Trower & Chait 2002), but qualified female doctoral applicants may be invisible to search committees. Search committees often lack gender diversity themselves, and their search activities often do not include systematic identification of the candidate pool, gender-blind screening of applications, and an equitable campus visit and interview process (Stewart, LaVaque-Manty, & Malley 2004). Conventional recruitment practices contribute to the homogenous replication of the faculty body; such practices are passive, time-limited, noninclusive and nondiverse, and search-committee members lack expertise in basic recruiting and hiring practices and are bias-prone (Bilimoria & Buch 2010).

Prior research has found that women and members of underrepresented minority groups are judged more fairly when they are at least 30% of the applicant pool (Heilman 1980; Sackett, Dubois & Noe 1991), yet this level of representation is difficult to achieve in academic STEM disciplines, where women represent, on average, less than 20% of qualified applicants. The increase in women PhD graduates holding postdoctoral positions in S&E is symptomatic of the barriers women face in entry to tenure track positions. According to the National Postdoctoral Association, a postdoctoral scholar ("postdoc") is an individual holding a doctoral degree who is engaged in a temporary period of mentored research and/or scholarly training for the purpose of acquiring the professional skills needed to pursue a career path of his or her choosing. A postdoctoral position is a critical transition stage in the academic pipeline, beyond which the number of women scientists and engineers continues to decline. As shown earlier in Figure 3.3, the proportion of women S&E doctorate holders who are in postdoctoral positions was 41% in 2006, increasing from 14% in 1973 through 31% in 2003.

Other research has shown that female applicants for academic positions tend to be evaluated less favorably than male applicants with identical qualifications, by both men and women. In one study of identical curricula vitae of a hypothetical male or female candidate for a faculty position, both men and women evaluators preferred male job applicants (Steinpreis, Anders, & Ritzke 1999). Another study found that female postdoctoral fellowship applicants had to be significantly more productive than male applicants to receive the same peer review score (Wenneras & Wold 1997).

Isaac, Lee, and Carnes (2009) performed searches for randomized controlled studies since 1973 of interventions that affect gender differences in the evaluation of job applicants. Their systematic review reaffirmed a negative bias against women being evaluated for positions traditionally or predominantly held by men. They also found that although interventions that provided raters with clear evidence of job-relevant competencies were effective, clearly competent women were rated lower than equivalent men for male sex-typed jobs unless evidence of communal qualities was also provided. They also noted that a commitment to the value of credentials before review of applicants and women's presence at or above 25% of the applicant pool eliminated bias against women. They concluded that "when ambiguity exists in an individual's qualifications or competence, evaluators will fill the void with assumptions drawn from gendered stereotypes" (Isaac, Lee, & Carnes 2009, 1444).

Analyses of S&E searches undertaken over multiple years at two research universities yielded the following findings: a statistically significant linear relationship existed between the percent of female and underrepresented minority (URM) applicants in the candidate pool and their inclusion on the short list; the level of representation of female and URM applicants on the short list was associated with the likelihood of hiring a female or URM candidate; and the majority of Native American, black, and "race-unknown" candidates were hired when there were more females on the short list (Bilimoria & Buch 2010). These findings highlight that the applicant pool and search committee practices to diversify this pool are critical elements in increasing faculty diversity.

Differences in the content of recommendation letters written for women and men candidates have been suggested as possible explanations for the difficulties women face in entering the academic pipeline. Trix and Psenka (2003) found systematic differences in letters of recommendation for medical school faculty positions for female and male applicants: their study documented that recommendation letters written for female applicants were shorter than those of men, lacked key information from their CVs, and were more likely to refer to their compassion, teaching, and effort while letters written for male applicants highlighted their achievements, research, and ability. Double the letters written for women applicants (almost 25%) raised doubts (e.g., by hedges, qualifiers, and faint praise) as those written for men applicants in this study (Trix & Psenka 2003). Another recent analysis of letters of recommendation for faculty applicants of a psychology department in a research university found other differences in the descriptions of women and men applicants (Madera, Hebl, & Martin 2009): after controlling for years in graduate school, number of publications, honors, number of postdoctoral years, number of courses taught, and type of position, the number of words per letter for women applicants in comparison to men applicants was significantly more likely to be communal adjectives (e.g., affectionate, helpful, kind, sympathetic, sensitive, nurturing, agreeable, tactful, interpersonal, warm, caring, and tactful) and social-communal orientation descriptors (e.g., husband, wife, kids, babies, brothers, children, colleagues, dad, family, they, him, and her), and less likely to be agentic adjectives (e.g., assertive, confident, aggressive, ambitious, dominane, forceful, independent, daring, outspoken, and intellectual). A second study conducted by these same authors provided evidence that that communal characteristics have a negative relationship with hiring decisions in academia that are based on letters of recommendation (Madera, Hebl, & Manin 2009).

The family situations of women and men are cited as relevant differences in academic STEM career entry and advancement (Mason & Goulden 2002, 2004). For example, while 70% of male tenured STEM faculty had children living in their home 12 to 14 years after earning a doctorate, only 50% of female faculty did (Mason & Goulden 2002). In this same study, 77% of the male faculty but only 53% of the female faculty who had babies within the first five years after receiving a doctorate had achieved tenure 12 to 14 years after earning a doctorate. Ginther and Kahn (2006) found that women are less likely to take tenure-track positions in science, but the gender gap is entirely explained by choices around fertility.

Significant in explaining the barriers to tenure-track entry is the *penalty for motherhood*. Examining the tenure-track positions at the University of California, Berkeley, Mason, Stacy, Goulden, Hoffman, and Frasch (2005) found that qualified female PhDs make up less than a third of the applicant pools. These same researchers observed that married women with and without young children are the least likely of all PhD recipients to secure tenure-track faculty positions (Mason et al. 2005). Correll, Benard, and Paik (2007) documented the existence of powerful schemas about parenthood in both laboratory and field studies. In the laboratory study, when evaluating identical applications, mothers were less likely to be recommended for hire, promotion, and management, and were offered lower starting salaries than nonmothers; evaluators rated mothers as less competent and committed to paid work than nonmothers; and fathers were seen as more committed to paid work and offered higher starting salaries than nonfathers. In the field study, prospective employers called mothers back about half as often as nonmothers, while fathers were not similarly disadvantaged in the hiring process (Correli, Benard, and Paik 2007).

Based on survival analyses of the Survey of Doctorate Recipients (a national biennial longitudinal dataset funded by the National Science Foundation and others 1981–2003) in S&E, and after accounting for a variety of control variables such as discipline, age, ethnicity, time to PhD, and PhD program ranking, married women with young children had 35% lower odds than married men with young children to get a tenure-track position, 28% lower odds than married women without young children, and 33% lower odds than single women without young children (Goulden, Frasch, & Mason 2009).

Related to these dynamics, women faculty members are particularly prone to *bias avoidance* with regard to their family lives. Drago (2007) documents that women faculty marry at lower rates than men faculty, are childless at higher rates, report having fewer children than they would like, and are less likely to utilize family-friendly policies (such as tenure clock extensions for the birth or adoption of young children) for fear that they may be penalized in future evaluations for using them.

Dual-career couples face a unique problem in higher education—obtaining tenure-track positions at the same institution, especially if they are in the same field. This issue is particularly salient for women S&E doctorate holders because 83% of them have academic partners who are scientists compared with 54% of their male peers (Schiebinger, Henderson, & Gilmartin 2008).

Women's Experience in Off-Track Positions

As noted earlier and in many other studies, women are more likely to be employed in nontenure-track positions, such as temporary teaching positions, research positions funded by "soft" or short-term restricted funding, part-time faculty, visiting scholars, adjunct faculty, postdoctoral fellows, and lower-level administrative positions (Harper, Baldwin, Gansneder, & Chronister 2001; Long 2001; National Science Foundation 2010). Individuals in these off-track positions are rarely provided opportunities for professional advancement, may not have their performance regularly reviewed or rewarded, may rarely find their positions converted to full-time or receive priority consideration when they are, and may be shut out of the faculty governance processes by the institutions that appoint them (American Association of University Professors 1993). At the entry point to an academic career, these factors already inhibit women's participation in S&E.

Pipeline Leaks after Entering the Tenure Track

Even after gaining tenure track S&E positions, women faculty face greater barriers in obtaining tenure, promotion, and advancement to leadership, and encounter more negative experiences in their workplaces, than do their male counterparts.

In a recent report entitled *Staying Competitive: Patching America's Leaky Pipeline in the Sciences,* Goulden, Frasch, and Mason (2009) found that family formation—most importantly marriage and childbirth—accounts for the largest leaks in the pipeline between PhD receipt and the acquisition of tenure for women in the sciences. Their findings indicate that women in the sciences who are married with children are 35% less likely to enter a tenure-track position after receiving a PhD than married men with children. Upon entering a tenure-track job, women in the sciences who are married with children are 27% less likely than their male counterparts to achieve tenure. Based on results from interviews, case studies, and statistical research, Rosser and Taylor (2009) concluded that the need to balance career and family and a lack of professional networks are the two primary factors that stand out among the multiple forces pushing women to leave the academic STEM workforce.

Barriers to Advancement to Tenure

Achieving tenure may be the most difficult hurdle of transition in academia. Female faculty are less likely to be tenured than male faculty (Long 2001). In a comprehensive study of almost 60,000 faculty members at 403 academic institution, Astin and Cress (2003) reported that male faculty attained tenure in a shorter amount of time than female faculty in all fields, with the exception of engineering. Other research has shown that women are less likely than men to receive tenure or promotion in STEM fields (National Science Foundation 2001; Rosser & Daniels 2004).

Croson and McGoldrick (2007) described the lack of clear communication about tenure requirements. In their study of women economics faculty, participants reported that they did not know how many publications would be necessary for tenure, or what the trade-offs were between fewer publications in top journals and more publications in lower-tier journals. Very few women faculty knew how important (or unimportant) it was to get grants, good teaching ratings, or do good service in the tenure evaluation.

Fox, Colatrella, McDowell, and Realff (2007) addressed three sets of conditions to support equitable evaluation, including more complete information on candidates' records and qualifications, clarity of evaluation standards, and open processes. The rationale is that bias in assessment is more likely to result if the criteria and process of evaluation are subjective, loosely defined, and a matter of judgment. "Non-performance-based characteristics, such as gender and race, are more likely to be activated as bases for evaluation when there are few relevant and known criteria on which to judge individual performance" (Fox, Colatrella, McDowell, & Realff 2007, 171). Secret and nonsystematic processes tend to activate "particularistic considerations" in evaluations; when criteria for evaluation are ambiguous, outcomes based upon race, gender, national origin, and other personal and social characteristics are more likely to occur.

The effects of implicit biases have been documented in the first authorships of scientific papers. After the journal *Behavioral Ecology* instituted double-blind reviews (where neither the identities of manuscript authors nor reviewers are revealed) in 2000, the proportion of female first authors increased significantly during 2002–07 as compared with 1995–2000. No such shifts occurred over the same time period in another journal with a similar subject matter and impact factor—*Behavioral Ecology and Sociobiology*—or with four out of five other ecology and evolutionary biology journals, most of which had continued to practice single-blind reviews (Budden, Tregenza, Aarssen, et al. 2008). The editorial team of one of these journals, *Journal of Biogeography,* which appeared to have an increased proportion of male-authored papers in Budden et al., subsequently conducted its own analyses of authorships over the three-year period 2005–2007, making special efforts to ascertain the gender of authors especially in previously unknown cases, and concluded that there was no difference in the acceptance/rejection ratio for papers submitted by male and female corresponding (not first) authors (Whittaker 2008).

Leakage also occurs from the lack of networks and mentoring of women in the S&E educational and career pipeline. Networks and mentors provide information and supports to a faculty member about how to conduct work, improve performance, and understand the political workings of the university system, as well as provide opportunities for collaboration and greater visibility in their discipline. Mentoring and peer support (Kram 1985, 1988) are important for professional connections (de Janasz, Sullivan, & Whiting 2003) as well as psychosocial benefits (Kram 1988). Mentored individuals are more likely to have higher compensation, greater salary growth, and more promotions than non-mentored individuals (Allen, Eby, Poteet, Lentz, & Lima 2004). Who mentors and who is mentored in academic S&E vary according to a number of individual and organizational factors (Fox & Conseca 2006).

Gender differences occur in the structure of mentor relationships in academic S&E as well as the resources obtained from these relationships: women's collaborative networks outside of their institutions are larger, and they matter for grant success—collaboration network size is positively associated with the probability of grant receipt, and women faculty have a lower probability of receiving a grant (Kiopa, Melkers, & Tanyildiz 2009). Previous research has shown that women faculty benefit from mentoring and institutional supports more than do men faculty (Bilimoria et al. 2006). As reported in the 2010 report *Gender Differences at Critical Transitions in the Careers of Science, Engineering, and Mathematics Faculty,* female assistant professors with no mentors had 68% probability of having grant funding versus 93% of women with mentors; the same was not found to be true for male faculty with and without mentors (National Academies 2010). Yet, access to mentorship is often more difficult for women and underrepresented minority faculty (Smith, Smith, & Markham 2000; Niemeier & (Gonzales 2004). Additionally, women S&E faculty have less diverse networks and fewer graduate and postdoctoral students to support their work than men faculty, and receive fewer referrals from their networks to consult in the commercial marketplace, serve on science advisory boards, and interact with industry (Murray & Graham 2007).

Barriers to Promotion to Professor Rank and Faculty/Administrative Leadership

Statistics also indicate that women are underrepresented in senior academic ranks and faculty leadership positions such as presidents, chancellors, provosts, deans, and chairs (Hollenshead 2003). The lowest proportion of women S&E faculty is at the highest professor level of the academic hierarchy. Among S&E doctorates who hold academic faculty positions in four-year colleges and universities, women are less likely than men to be full professors and more likely to be assistant professors (National Science Foundation 2006, Figure H-5). Fewer differences in rank exist between male and female faculty in early-career stages in S&E, but greater differences appear between 15 and 20 years after receipt of the doctorate (National Science Foundation 2001, Figure H-5). In the top 50 U.S. universities, women comprised only 3% to 15% full professors in various fields S&E (Nelson 2007).

A nationwide study of faculty at four-year colleges and universities showed that women associate professors are 10% less likely than men to attain promotion to full professor even after accounting for productivity, educational background, institution type, race, ethnicity, and nationality (Perna 2001). More recently a focus-group study of the advancement of women and men associate professors at the Massachusetts Institute of Technology found similar results—women are less likely to be promoted to full professor than men and take longer to achieve promotions (Misra, Lundquist, Holmes, & Agiomavritis 2010).

In a comprehensive critique of the appointments of women to professor rank in Dutch universities, van den Brink (2010, 214) has systematically deconstructed the various ways in which gender is practiced in the most senior academic appointments—"supposedly gender-neutral organization processes, such as the implementation of transparency policies, the search for talent and the construction of scientific excellence, have been exposed as being based on hierarchical conceptions of masculinity and femininity." Her findings expose and refute prevalent myths explaining the low numbers of women professors, including the myths that (1) there are too few professorial positions available, (2) there is too little female potential for these positions, (3) professorial appointment practices are transparent and decision makers are held accountable, (4) professorial recruitment is a level playing field, (5) the concept of scientific excellence can be defined and is gender neutral, and (6) gender practices are similar in all academic subfields (van den Brink 2010).

In a related study, van den Brink, Benschop, and Jansen (2010) shed light on how norms of transparency and accountability are implemented in highly gendered ways. They describe numerous subtle practices by which micropolitics—the myriad strategies and tactics of exerting informal and formal influence to further personal interests—surround the implementation of these norms at every stage in the professorial appointment process. For example, although norms of transparency and accountability drive efforts to diversify appointment committees, women committee members are most often doctoral students or human resource specialists whereas men members are professors. While vacancies are advertised in the media, in reality the preferred candidate is already known and any other applicants are part of a purely cosmetic appointment procedure. Often special chairs are created and offered to women candidates in closed recruitment procedures, thereby inflating the number of women in chaired appointments; however, such women's chairs are often temporary and their legitimacy is disputed. Women candidates are only selected when they are "excellent" beyond all doubt, whereas the standards are broader when exercised for men candidates. Based on these and other findings, the authors conclude that "it is often difficult to enhance gender equality because of the existence of multi-faceted gender inequality practices alongside gender equality practices that lack 'teeth', especially in a traditional masculine academic environment with ponderous traditions and 'thick' values. . . . We conclude that gender inequality practices continue to dominate and that they detract from, distort, or even hijack attempts to introduce gender equality practices" (van den Brink, Benschop, & Jansen 2010, 1478–1479). Three policy approaches are offered to address these shortcomings: (a) to deploy the tools of transparency and accountability to their full potential particularly by making the process and decisions more visible for the larger academic society, (b) to enable university boards to monitor compliance to the regulations and put in place the incentives and sanctions that can ensure full implementation, and (c) to utilize multiple perspectives on gender equality in training to make committee members aware of double standards and routine gender inequalities in the appointment process (van den Brink, Benschop, & Jansen 2010).

In addition, a recent study of NIH awards found that more experienced researchers (those who have already received R01 grants) who submitted and received renewal applications were more likely to be male (Pohlhaus, Jiang, Wagner, Schaffer, & Pinn 2011). The study found an inverse correlation between age and the participation/success of women in NIH award programs in three ways: there were fewer women applicants and awardees for awards targeted at higher average ages, more experienced women researchers were less likely to apply and receive R01 grants than first-time women researchers, and investigators with multiple concurrent R01 awards were older and more often male than investigators with one award (Polhaus et al. 2011).

Women are also more likely than their male colleagues to be under-represented in administrative and leadership positions (e.g., department chairs, deans, and senior administrators). For example, only 10.31% of permanent deans of medical schools (13 out of 126 in 2009, up from 12 out of 126 in 2006) were women (Association of American Medical Colleges 2009). Among science and engineering doctorate holders in academia, women were 27% of deans and 30% of presidents of colleges and universities (National Science Foundation 2009).

A common myth about the pipeline is that achieving greater proportions of women in senior academic positions is merely a matter of time—that as the pipeline fills more women will occupy senior positions. However, the popular myth that there are insufficient numbers of women in the pipeline is not supported by the data (Trower & Chait 2002). As pointed out in *Beyond Bias and Barriers,* "For over 30 years, women have made up over 30% of the doctorates in social sciences and behavioral sciences and over 20% in the life sciences. Yet, at the top research institutions, only 15.4% of the full professors in the social and behavioral sciences and 14.8% in the life sciences are women" (National Academies 2007a, 2).

In summary, while considerable progress has been made over the years, women faculty are still less likely to achieve tenure, advance to professor rank, and occupy administrative and faculty leadership positions.

Women's Experience in the Tenure Track

A variety of problems emerge from the lack of a critical mass of women and few women at the top of the academic hierarchy in STEM, particularly resource inequities, barriers, and problems related to differential treatment and evaluation at every level in the institution. The groundbreaking study conducted by the School of Science's Committee on Women Faulty at MIT (Massachusetts Institute of Technology 1999) indicated the marginalization and exclusion of senior women faculty (in particular) as academic colleagues, documenting their receipt of lower space, salary, and other resources, exclusion from informal and formal social gatherings, and exclusion from research and teaching collaborations. Other studies have documented a persistent gender gap in salaries (West & Curtis 2006); female faculty members earn significantly less than male faculty members even after controlling for human capital, scholarly productivity, and personal characteristics (National Science Foundation 2003). Additionally, women have less access to research assistance and funding than men (Creamer 1998; Xie & Shauman 1998), and they enter academic positions with more limited start-up packages, less office and lab space, and less graduate-student and support-staff assistance (Massachusetts Institute of Technology 1999; Park 1996).

Rosser (2004) reported that low numbers of women S&E faculty result in women feeling isolated, having limited access to role models and mentors, and having to work harder to gain credibility and respect from their male colleagues (see also Fox 2010). With constrained access to key academic networks, women junior faculty are left on their own to learn how to navigate the promotion and tenure process in a male-dominated environment. Many women opt out of academic S&E, choosing private-sector positions because they become frustrated with the academic setting (Valian 2004). Noting the clustering of most female professors at the assistant professor level, Nelson (2007) suggests that the number of female faculty who can safely take steps to change their departmental environments is much smaller than it might first appear.

In two waves of early focus groups and interviews about the career experiences of women faculty members at a research university between 2001 and 2004, the researchers found several important themes including: (1) an overall chilly climate and unwelcoming community for women described by participants as exclusionary, unfriendly, marginalizing, tough, isolating, male-dominated, and silencing; (2) a climate where 'everything is negotiable,' manifested in perceptions of side deals and of unequal application of procedures; (3) lack of transparency in university rules, policies, procedures and practices; (4) a pervasive lack of mentoring; (5) disproportionate service and teaching pressures faced by women faculty; and (6) unfair or unequal access to/allocation of resources, including purchase of library materials, assistance from teaching assistants, access to services from support staff, travel money, and protected research time (Case Western Reserve University 2003). Other writings address the multiple dimensions of gender-based resource inequity in academia (Long 1990, 1992; Evetts 1996; Preston 2004; Valian 2004). For example, women faculty receive less office and lab space, have less access to graduate-student assistance, and get fewer services from support staff (Park 1996).

The experiences of women faculty in STEM seem to derive from particular sets of beliefs held by (predominantly male) faculty and administrators. For example, participants in the focus groups mentioned above brought out the notion that leadership seems naturally male, and that masculinity appears to lead to power, manifested in conscious and unconscious ways at the university. Other beliefs regarding academia voiced by participants included that the academic enterprise requires complete dedication at the expense of everything else, especially in early-career years, and that academia is essentially an individual profession, with individualized results and rewards.

These mind-sets contribute directly and indirectly to the treatment and evaluation of women faculty. Similar other belief structures, detrimental to women in academia, have been identified by research from other institutions as well. For instance, Silver et al. (2006) summarize several factors that retarded the achievement of full professional equality at the University of Rhode Island, as mentioned in a December 2000 independent audit team report stemming from a grievance settlement to a claim of sexual harassment in the College of Engineering: "a belief that some male professors and administrators did not view female colleagues as equals but rather as second-class members of the faculty. Adding to the women's discomfort was their perception that individuals who raised complaints about disparate treatment were viewed as 'troublemakers,' a perception that discouraged the seeking of redress for mistreatment" (Silver et al. 2006, 3). These factors included: demeaning and insulting statements and remarks made by the dean and faculty members toward women faculty; "window-dressing" efforts by the dean to support women in engineering programs rather than providing adequate funding for such efforts; public treatment of women faculty in a less respectful manner than male faculty; and commenting to women faculty on the perceived appropriateness of their clothing (Silver et al. 2006).

Prior research has described how the masculine image of academic S&E work translates to the treatment and evaluation of women in the workforce. Van den Brink and Stobbe (2009, 451) note that "the most important factors (re)producing gender inequality at universities relate to the images of science, scientific practice and the ideal scientist." Research careers in S&E, in particular, are perceived to demand a single-minded, full-time focus on a specific topic, exclusive devotion to career, and aggressive self-promotion (Dean & Fleckenstein 2007). A prevalent image is that of a scientist or engineer as a man hard at work in a laboratory during all hours of the night and weekends. The ideal worker concept (Acker 1990, 1992) suggests that "the abstract worker is actually a man, and it is the man's body, its sexuality, minimal responsibility in procreation and conventional control of emotions that pervades work and organizational processes" (Acker 1990, 152). Benschop and Brouns (2003) suggest that the image of the *ideal academic* represents a faculty member fully absorbed in his research program, and Bailyn (2003, 139) describes the *perfect academic* as someone who "gives total priority to work and has no outside interests or responsibilities." These powerful cultural images suggest that academic scientific research is exclusionary of women, contributing greatly to the negative experiences of women.

The chilly climate for STEM students has been described previously (Hall & Sandler 1984; Mills & Ayre 2003). For example, from their study of computer-science women and men undergraduate students at Carnegie Mellon, Margolis and Fisher (2002) found that the overwhelming image of a computer science major is the "geek," which more than two-thirds of the women (and almost one-third of the men) interviewed said did not fit them. "The rub for women in computer science is that the dominant computer science culture does not venerate balance of multiple interests. Instead the singular and obsessive interest in computing that is common among men is assumed to be the road to success in computing. This model shapes the assumptions of who will succeed and who 'belongs' in the discipline" (Margolis & Fisher 2002, 71). As these authors put it, "A critical part of attracting more girls and women in computer science is providing multiple ways to 'be in' computer science" (Margolis & Fisher 2002, 72), not just one linear path. Similar concerns were raised by women engineering students in the UK—interview findings revealed that women students had good experiences (mostly regarding peer and instructor support and relationships, and the opportunity to have an internship experience in industry), bad experiences (mostly regarding structural issues such as teaching and learning methods, and curriculum content and relevance), and ugly experiences (mostly regarding people's attitudes toward women students and everyday negative occurrences) (Powell, Bagilhole, & Dainty 2007).

From interviews with 80 female faculty members at the University of California, Irvine, the authors concluded that "Where power operates behind the scenes, subtly shaping structures of daily life and political beliefs, the assessments of those subject to its oppressive impact are adaptive and their responses challenge it indirectly. Our speakers, for instance, show a keen understanding of where the Academy stands relative to the necessary sacrifices all its participants must make in terms of family life" (Monroe, Ozyurt, Wrigley, & Alexander 2008, 231). For these women faculty "the concept of professional success needs to be redefined so it allows for alternative models, not simply the traditional, linear male model in which the professional is full time and focused on a career, with few family duties" (Monroe, Ozyurt, Wrigley, & Alexander 2008, 231).

Results of various interview and climate studies indicate the everyday experience of women faculty in S&E fields. In a cross-institutional study of 765 faculty conducted in eight research institutions during 2002–2004, Fox (2010) reported that women are less likely than men to report speaking daily about research and more likely than men to report speaking less than weekly. Women also gave significantly lower ratings of access to equipment and lower recognition from faculty colleagues in home units (e.g., departments), and were significantly less likely than men to characterize their home units as (a) informal (compared to formal), (b) exciting (compared to boring), (c) helpful (compared to unhelpful), (d) creative (compared to noncreative), and (e) inclusive (compared to noninclusive). In another climate study conducted at a large public university, in comparison with their male counterparts, STEM women faculty reported significantly lower equality of treatment, perceived the organizational climate as significantly less supportive, perceived lower support for family friendliness, reported more overt discrimination in areas such as salary, promotion, and access to resources, perceived that they undertook greater service involvement, and believed that their departments viewed them as less productive than their departmental averages (Blackwell, Snyder, & Mavriplis 2009).

Results from interviews with women and men faculty members at another research university indicated that female faculty were more likely to report negative interactions with colleagues, negative experiences with the process of evaluation, promotion and tenure, difficulty balancing work and family life, and overwhelming workloads (Hult, Callister, & Sullivan 2005). Several other climate studies conducted by universities indicate that male faculty experience more favorable interpersonal relations than women faculty. Tenure-track women faculty often provide lower ratings than their men counterparts on items measuring institutional support, such as child care, career planning, teaching improvement, tenure-clock adjustments, and accruing resources. In addition, female faculty on the tenure track report lower satisfaction with their academic jobs than do male faculty (Bilimoria et al. 2006; Callister 2006), and they are more likely to opt out of academic S&E (Valian 2004). In a sample of 248 nonmedical faculty members, Bilimoria et al.(2006) found that women's job satisfaction derived more from their perceptions of the relational support provided to them in their departments than the academic resources they received, whereas men's job satisfaction resulted equally from their perceptions of resources and relational supports received. Similarly, Callister (2006) noted that female faculty members are not inherently unsatisfied or unhappy with their jobs, but rather that they greatly value department climate.

A valuable concept from sociology addressing the experience of women faculty in S&E is the *accumulation of advantage,* which is the magnification of initial small differences into later large differences (Merton 1942/1973). Initial small advantages operate over time and may add up to larger advantages over the course of a career (Long 1992). Valian (1999) likens the accumulation of advantage to interest accruing on capital and the accumulation of disadvantage to interest accruing on debt. The impact of accumulative disadvantage on the career outcomes of S&E women is recognized. For example, the 2001 report, *From Scarcity to Visibility: Gender Differences in the Careers of Doctoral Scientists and Engineers,* noted that "while controlling for background differences eliminates much of the gender difference in salary, it does not eliminate it altogether . . . Further, with each progressive stage of the stratification process, it becomes more difficult to distinguish outcomes that are the result of individual differences between women and men from the result of men's cumulative advantage over women in science" (Long 2001, 216–217). A demonstration of the effects of accumulative disadvantage showed that very small differences in how individuals (or groups) are treated can result in very large disparities in career outcomes (Martell, Lane, & Emrich 1996). In this computer simulation of organizational promotion practices, the effects of a small disadvantage for females in promotion through eight hierarchical levels were modeled. The disadvantage accounted for only 1% of the variability in promotion. The researchers ran the simulations with the lowest organizational level equally staffed by males and females. After the eight minutely advantaged moves, the highest level in the hierarchy was staffed by 65% males.

Institutional Transformation to Repair the Leaky Pipeline

A burgeoning literature has begun to emerge around institutional approaches to address the issues described above and repair the leaky pipeline. The participation, status, and advancement of women in academic S&E have been recognized as organizational issues, which are subject to organizational transformation (Rosser & Lane 2002; Fox & Colatrella 2006; National Academies 2007b; Stewart, Malley, & LaVaque-Manty 2007; Fox 2008). Simplistic, ad hoc, and piecemeal solutions, or those that focus only at individual-level, "fix-the-women" type interventions, cannot eradicate systemic, historical, and widespread gender underrepresentation and inequities. Instead, a comprehensive transformation of the organizational systems, structures, processes, policies, practices, and mental models that perpetuate inequity is needed (cf. Thomas & Ely 1996; McCracken 2000; Meyerson & Fletcher 2000; Rosser 2004). Such change calls for the reorganization of the core elements of the institution, including mission and vision, goals, accountability, authority, decision making, policies, and practices (cf. Levy & Merry 1986; Nutt & Backoff 1997; Kezar 2001; Fox 2008). In short, as recommended by Rosser (2004), what is needed for a brighter future is a "change the institution, not the women" approach.

Drawing on earlier writings about change in higher education (e.g., Astin & Associates 2001; Eckel & Kezar 2003), Fox (2008) has described institutional transformation in higher education as change that is systematic, deep, intentional, and cultural. Transformation in higher education is systematic in that it involves alteration in the full range of functioning parts of the institution; transformation is deep to the extent that it affects values and assumptions, as well as structures and processes in higher education; transformation is intentional because it involves deliberate and purposeful decision making about institutional actions and directions; transformation in higher education is cultural because it involves the dominant and prevailing patterns of assumption, ideologies, and beliefs that people have about their organization and that shape their attitudes, priorities, and actions regarding teaching, research, and service (Fox 2008; see also Eckel & Kezar 2003).

An institutional change lens on gender equity, diversity, and inclusion concerns, rather than an individual change approach, has been recommended by a number of reports and studies. For example, the 2007 report *Women, Work, and the Academy* recommended that "Rather than making it a priority to change women and minorities so that they fit academic institutions in their current configuration, adopt strategies for changing those institutions so that they are more inclusive on a number of dimensions. These strategies should include pathways to professional success that do not pose intractable conflicts between work and the rest of life" (Wylie, Jakobsen, & Fosado 2007). Looking at the full system of S&E in the country, the National Academies' (2007a) *Beyond Bias and Barriers* report provided institutional transformation recommendations not only for universities but also for professional societies and higher-education organizations, federal funding agencies and foundations, federal government agencies, and the U.S. Congress.

In an early forerunner, Rosser (1993) proposed that overcoming the pervasive male orientation of science requires recognition of gender bias and creation of gender-equitable science content and teaching. She proposed proceeding systematically through the following six phases of change: (1) the absence of women in science is not noticed, (2) recognition that most scientists are men and thus science may reflect a masculine perspective, (3) identification of barriers that prevent women from entering science, (4) search for women scientists and inclusion of their contributions, (5) recognition that science is done by women, and (6) redefining and reconstructing science to include all (Rosser 1993).

Borrowing from the smoking-cessation literature, another framework to understand the phases of diversity-related institutional transformation was proposed by Carnes, Handelsman, and Sheridan (2005). They posit that institutions seeking transformation go through five stages of change: (1) precontemplation (unawareness that a problem exists), for example, where the institution engages in no dialog no resources; (2) contemplation (awareness that a problem exists and thinking about making a behavioral change in the future), for example, where the institution may sponsor workshops, discussions, task forces, and committees around diversity matters; (3) preparation (feeling confident that making a change is possible and planning to make a change in the immediate future), for example, where the institution may offer resources (e.g., for targeted hiring initiatives) or training (e.g., for search committees); (4) action (making a change), for example, where the institution undertakes specific initiatives to accomplish the goals; and (5) maintenance (continuing to engage in the new, desirable behavior and avoiding relapse), for example, where the institution provides rewards and reinforcements for new behaviors, and undertakes data monitoring and policy reviews. According to these authors, transformation is most successful when appropriate interventions target the institution's stage of change.

While focusing on institutional transformation to increase women students, Margolis & Fisher (2002) recommend that departments undergo programmatic changes to improve their cultures and curricula, improve the attitudes and beliefs of male faculty and students through education, and engage in systemic changes in outreach, recruitment, and admissions activities that focus on increasing women students. Proposing a similar focus on creating a more inclusive culture, Whitten et al. (2007) have suggested that in the context of physics, undergraduate education departments think of pathways rather than pipelines to actively recruit and retain women students (see also Whitten et al. 2003).

Drawing on contrasting metaphors of soccer and football to describe the everyday experiences of female and male faculty, Cress and Hart (2009) recommend a fundamental rethinking of the equation between research, teaching, and service in academic reward systems by: (1) challenging search committees and promotion and tenure committees to reward scholarship that is emerging in new areas including interdisciplinary scholarship and support diverse ways of working and time allocation, (2) systematically collecting data about service commitments as well as hidden workloads and responsibilities, (3) better compensating faculty who contribute disproportionately in service and teaching areas, and (4) providing release time and research support for faculty with extraordinary teaching and service responsibilities.

Valian, Rabinowitz, Raps, & Pizer (2004) have made other suggestions for institutions seeking to improve equity, diversity, and inclusion of women in academic science careers, including taking a "fix the institution, not fix the woman" approach, teaching decision makers about how schemas about gender and race disadvantage people in the workplace, performing frequent reviews of hidden and subtle forms of bias, training oneself and other evaluators to correct errors in evaluation and decision procedures, communicating information equally to men and women about the criteria for success at the institution, ensuring equal job responsibilities, participation in public settings and service duties of women and men, implementing consistent policies for recruitment, training, appraisal, mentoring, and development to both men and women, understanding that equity will not be achieved or sustained without special effort, and committing to making and institutionalizing that effort. Focusing specifically on faculty development needs as a change strategy, and proposing a vision of a new type of system based on a holistic, long-term view of faculty careers, Laursen & Rocque (2009) recommend transformational actions that focus on three tiers of faculty development needs: individual career stage-specific needs (early career skills, mid-career skills, and late career exploration), organizational needs across career stages (community/collegiality and department life), and systemic needs (reward system, work-life balance, diversity, and other systemic concerns).

While there have been many recommendations regarding the kinds of changes and approaches to change, to date, however, there has been little systematic study of the outcomes of institutional change in higher education pertaining to the inclusion and advancement of women faculty in S&E. Few longitudinal analyses and sustained research projects are in place, and there are many gaps in our knowledge that need exploration, particularly with regard to the results of change efforts underway (Kezar 2001). Most glaring is the lack of a comprehensive theory of change that underlies successful institutional transformation to engender equity, diversity, and inclusion. The lack of such theory to guide transformational efforts at universities and colleges has been particularly vexing for institutions seeking change. As Laursen (2009) has commented, articulating a theory of change and its underlying assumptions has been a challenge for many institutional-change projects. Particularly for issues such as women's workforce participation, equity and inclusion in STEM higher education, identifying a theory of change is inherently difficult: the desired change is large and difficult, the context is complex, and the root causes are multiple and interconnected (Laursen 2009).

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CHAPTER 4

Walking a Tightrope: The Feminist Life of a *Drosophila* Biologist

Marta Wayne

Despite widely reported success in increases of the number of women enrolling in graduate school, the androcentric focus of science remains present in biology at every level: from what questions are asked, to what answers may be considered, to who may ask/answer the questions. This is an increasing problem for me both personally, as a woman who is a scientist and a feminist; and politically, because of the ever-increasing presence of science (particularly my field, evolutionary genetics) in people's lives. The continuity between the ways that assumptions of the male as norm occlude my field from the interpretation of data to the training of women scientists is discussed. The growing scholarship in feminist science studies offers the hope of a better science and a better climate for feminist scientists, but communication between women's studies and life sciences professionals is as yet at an early stage.

The last decade of feminist scholarship on the sciences has produced an impressive array of new research on the reciprocal relationship between scientific knowledge and gender inequalities.[1] Though much of this work has been undertaken by researchers in the humanities and social sciences, some of this work has been informed by feminists in the sciences who are writing for publications outside of the sciences about topics that scientists usually do not address. Their work has added scientific specificity to feminist critiques of the methods and theories of a masculinist science. Yet the work that would extend feminist theoretical insights into revising and/or rebuilding contemporary scientific theory, which is what some would call "feminist science," is just beginning.[2] As a scientist who is also a feminist, such an effort promises an intellectual home, but the task is daunting nonetheless.

It is often the case that matters related to the "climate" for women in science are set apart from a focus on the substantive influences of gender constructs on knowledge. I propose that these are more entangled than such a division suggests. It is not only that the methods and theories of a masculinist science are at play in shaping content; it is also that those theories and methods contribute to the working environment of women in science. In my field, evolutionary genetics in *Drosophila* (fruit flies), male-centered gender norms are naturalized through interpretations of *Drosophila* behaviors and then reasserted as paradigmatic dichotomized sex differences that legitimate the major and minor insults of a chilly climate.

I do research on structures in the ovary in *Drosophila*. Though my research is grounded in a challenge to the assumption that the developmental processes of male *Drosophila* represent the developmental processes of all *Drosophila,* I reject the belief that these sex differences are relevant to understanding human social behavior, though I see my research as potentially contributing to understandings of women's bodies. I take this position in a context in which it is taken for granted that it is scientifically useful to extrapolate human behavior from *Drosophila* model and that the male is the norm.[3]

In my field, models for evolutionary adaptation are developed from *Drosophila* experiments. I recently conducted a study of viability in *Drosophila* (Wayne et al. 2000). Viability in this context means whether or not the insect can survive from an egg to an adult, metamorphosed fly. Viability is a classic trait of central importance to evolution, and it has been studied for decades. However, no one had ever asked whether or not females and males have the same genes for viability. When I designed my experiment, I collected the data separately for the two sexes, and interestingly enough, the genetic architecture of viability is different between females and males. However apparent or obvious this may be to you, reader, it is news to most people in my field.

Scientists have known for many years now that there are genes that cause death in one sex and not the other: genes with names like *daughterless, sex lethal, sisterless,* etc. (and the negative association is surely not coincidental). In fact, the discovery and analysis of these mutants is how one of the crown jewels of developmental genetics, the *Drosophila* sex determination pathway, was elucidated. But the connection between the existence of these mutations and the possible differences in the genetic architecture of viability between the sexes had not been made because the conventions of the field presumed that males were "relevant" and females were not. Those conventions limited the experiments. They limited what could and could not be embraced as valid data and they limited the interpretive options available to scientists. The conventions so limited the field that they drove interpretations of contrary evidence.

For example, way back in 1948, Bateman wrote a paper about how often female flies will mate in the laboratory. The paper is used in textbooks (Krebs and Davis 1993; Drickamer et al. 1996; Futuyma 1998) as the classic study demonstrating a central tenet of animal behavior, that females will be the choosy or "coy" sex, while males will mate with anything that crosses their path. The idea is that since eggs are larger and fewer than sperm, females make a greater investment in their offspring than males do, so they have to make sure that their fewer offspring get the best possible father. Bateman's data are said to show that a female fly will mate only as often as necessary—once or twice—to ensure fertilized eggs for the rest of her life. However, a careful review of the paper reveals that Bateman's data do not support this at all; female flies mate far more often than is necessary to ensure a lifetime supply of sperm. Furthermore, Bateman's interpretation of his data makes a much more limited claim. Yet his paper is widely miscited by scientists, and is described as demonstrating "Bateman's Principle" (e.g., Arnold 1994) or "Bateman's Rule" (e.g., O'Connell and Johnston 1998).

In her landmark essay on the myth of the coy female, Sarah Blaffer Hrdy discusses Bateman in the broader context of sexual selection and primatology (Hrdy 1987). She emphasizes that it was the increased presence of women as researchers that prompted a substantive revision of the coy female paradigm, because these women asked different questions. Hrdy argues that "women scientists were less likely than male scientists to identify with authority and with the scientific status quo . . . they may have been more willing to entertain unorthodox ideas about sex roles" (Hrdy 1999, xix). But since Hrdy did not admit to or endorse a specifically feminist agenda, her critique of Bateman addressed only the scientific inadequacy and inaccuracy of the "coy female" paradigm, but not the enduring commitment to it. She raised questions about the paradigm, but did not posit alternatives.

Since Hrdy first critiqued Bateman's rule in 1987, there has been a plethora of work that shows that female flies are anything but coy. In the wild, they'll mate more than ten times (Imhof et al. 1998). In fact, female flies will mate so readily that male flies have evolved special qualities to ensure that their sperm are the ones that fertilize the eggs, not the male before or the male after. Despite these additional observations, many researchers fail to note the (continued) contradiction between *Drosophila* data and Bateman's Principle or fail to grasp the full import of it, in that they continue to interpret mating in terms of male-centered concepts.

For example, one metaphor refers to "sperm competition" to capture a biological outcome of females' mating practices. A football analogy is widely used to describe two phases: offense, to get rid of the sperm of the preceding male, and defense, to resist the offense of the following male. Some people prefer to call it "sperm precedence" instead (Baker and Bellis 1988; Bellis et al. 1990), but either way the female's central contribution disappears.

Conflict theory is another popular metaphor in evolutionary biology. According to this theory, the interests of females and males often, necessarily, conflict because of the differential investment in gametes (eggs and sperm) and in offspring. The crux of conflict theory is that males should have as many offspring as possible, since sperm are small and "cheap" to produce from a biological energetics point of view. However, females can not have as many offspring as males, since eggs are large and biologically "expensive" to produce. According to this theory, because they are limited in this way, females must be more choosy (coy) than males, making sure that their fewer gametes get the best possible sperm. The theory expands to include differential parental care between the sexes, gestation time, and "costs" of mating. Conflict theory itself is influenced by Bateman, because persistent distortions of his interpretation sustain the belief that while males will re-mate as often as possible, females will not (1948).

An emerging theory about "female resistance" is perhaps a first step away from male-centered interpretations. Female resistance has to do with how the female deals with sperm from more than one male inside her reproductive tract. In this model, some females use the sperm of males that mate first, and some use the sperm of males that mate second, and so on; in other words, paternity is strongly influenced by some capacity of the female. Indeed there is a large body of recent literature on the subject with titles like: *Female Control: Cryptic Sexual Selection* (Eberhard 1996). Yet even here there are persisting and pernicious assumptions about the centrality of males to reproduction. Again females are defined in relation to males; they are *responding to* a male strategy rather than *acting* independently—"females are normally evolving *in response* to male variation" (Clark et al. 1999, 218). Female response is graphed as an interaction, rather than as a main effect, with the focus remaining on "the relative success of sperm"(219).

Rather than developing models of female response to sperm precedence, researchers could focus directly on female behavioral physiology. However, the field of scientifically credible ideas does not include this as an option; it may take a feminist political stance to stretch to the "unimaginable." If science were the product of a woman-centered society rather than a patriarchal one, we might be modeling strategies of the female to use the sperm she wanted while participating in as many matings as she pleased, and males would respond to *her* manipulation of *them.*

Unfortunately, the interpretive framework for sperm precedence is extrapolated to *people.* According to the National Institute of Health and the National Science Foundation, my sources of funding, flies are a model organism for humans.[4] Thus, conceptual limitations in interpreting data from fruit flies translate directly into myopic research and interpretation of data in humans.

The concept of model organisms is that since genes in flies and humans ultimately come from a common ancestor, by studying genes in a simpler, more malleable system such as a the fly, we can learn about the function of related genes in a more complex system: *homo sapiens.* Developing model systems in insects and animals is a hallmark of contemporary biology, and this approach has proven medically useful for some narrowly biological topics. It becomes rather more problematic when scientists extrapolate behavior and its genetic underpinnings from the simple brain and genome of a fly to the complex brain and genome of people. Yet *Drosophila* research has given rise to empirical studies on male sperm competition in humans (Baker and Bellis 1989; Baker and Bellis 1993a, 1993b).

Bateman's rule has been used to explain rape (because men, like male flies, are "selected" to mate with as many females as possible, and to interpret no as yes; and women, like female flies, are "programmed" to say no when they mean yes) (e.g., Thornhill and Thornhill 1992), sexual harassment (same general ideas), gendered theories of jealousy (males will be jealous of promiscuity on the part of females, but females will not care if males are promiscuous as long as they continue to provide resources) (e.g., Buss 1991), and a lot of other ugly cultural norms thanks to the "new" science of evolutionary psychology. These publications have found an outlet in a variety of arenas, from apparently feminist compilations (Wilson et al. 1997) to law reviews (Kennan 1998) to popular science books (Pinker 1998). In these contexts, conflict theory becomes an apology for inequality, a statement that biologically speaking, the interests of females and males are inherently in conflict even at the level of the cell; to phrase things in terms of conflict is to imply winners and losers or, at best, détente.

It would be simplistic to argue that conflict theory in evolutionary biology underwrites the educational context for scientists, but there is a resonance. Competition for resources is characteristic of contemporary scientific research. Undergraduate, graduate, and postdoctoral training all involve learning how to negotiate interpersonal and intellectual conflicts. Such conflicts are understood as necessary and unavoidable components of the process of identifying and cultivating the "winners." As a woman, I notice, I have noticed, I will continue to notice, the symbolic resonance between male-centered biological theory, where "females" are under-stood as secondary or irrelevant, and male-centered education, where male and female students are taught the biological theory.

As a graduate student, I survived my training by learning to interpret my day-to-day experiences with colleagues in the lab in feminist political terms, but I interpreted my research in a "less political" way. As my exposure to feminist critiques of science has grown, I have come to understand this interpretation as an accommodation to the belief that science is value-neutral. I have learned that feminist perspectives are crucial to transforming scientific knowledge, that my feminist perspective has refreshed and invigorated my science.[5] I have also concluded that the androcentric bias that presumes the male as norm, the only sex worthy of study, is the same one that creates a climate hostile to women scientists.

In retrospect, this shift occurred in four distinct phases, beginning with acceptance of the status quo, then a questioning of the gender politics in my social environment, and then an increasing awareness of how deeply beliefs about gender differences infect scientific knowledge. I am now presented with phase four, where unsettling questions are emerging about how my research could be used by others to fuel human sex-difference research.

PHASE 1: I LOVE SCIENCE. WHAT PROBLEM?

When I first began as an undergraduate science major, I had no idea of the politics of the lab environment, never mind gender politics. In my first research position, I was supervised by a wonderful man, Dr. S., who shared my most important passions in life: science, science, and surfing. I was the only other person in his laboratory. He taught me all kinds of complicated and demanding biochemical techniques. Dr. S. was full of positive reinforcement. He answered all of my questions seriously, and made me feel smart for asking them. Together we solved technical problems as they arose, and improved the experimental protocol based on the results of the early experiments.

We worked hard, but we also had fun together. Every day at lunch we surveyed the surf and wind conditions, and if the waves were especially good we would take off and surf during the afternoon, returning to finish the day's work in the evening. Dr. S. took advantage of these times to talk about the various paths one might take as a scientist, and the pros and cons of each. The work itself went splendidly, yielding great results. In group-wide lab meetings, and when scientists visited from other institutions, Dr. S. tirelessly promoted me and my work, rather than appropriating praise and credit as my supervisor.

Unfortunately, we got along so well, and enjoyed working together so much, that everyone else in the research group assumed we were sleeping together. Because I was quite naïve, and because the other members of the group rarely set foot in our lab, I did not learn about this gossip until the end of the summer. I was very angry, and very hurt. Our shared excitement was about science, not sex; a platonic relationship had been sullied by this accusation. The reason that this was so upsetting was because my colleagues apparently thought that a scientist like Dr. S. couldn't possibly find a mere female undergraduate intellectually exciting, and that therefore our relationship must have been based on something else, namely sex. The fact that Dr. S., equally angry, commented that this would probably happen throughout my career, did not exactly alleviate my hurt and anger. Surely it would be different in another laboratory.

During the next school year and the following summer, I worked in another lab, with the person who became my undergraduate advisor, Dr. D. He was everything I thought a scientist should be: brilliant, famous, kind, witty, and grandfatherly. Surely no one would think I was sleeping with HIM. On my first day of work, Dr. D. introduced me to three men (Dr. X., Dr. Y., and Mr. Z.) with whom I would be sharing a very small lab. He explained to them that "since I was a young lady, he hoped that they would behave themselves and watch their language." This had little effect. Dr. X. spoke to me only in a snarl and took every opportunity to make me feel stupid and inadequate. At the time, I consoled myself with the hope that he did this because he feared that I was smarter than he was. Dr. Y. swore at me repeatedly, and made remarks about my legs, as well as making more obscene comments.

My only sometime ally was Mr. Z., who was addressed by the other two as "camel driver" and "rug trader" because he was Middle Eastern. The three of them routinely discussed their plans to get together in the evenings and on the weekends to drink beer or go to baseball games but never asked me to join them. I thought that my excluded status was all part of the game of learning to be a scientist and that I should be tougher. I concluded that I should focus more on my fruit fly experiments. The point was to uncover the secrets of nature, right?

PHASE 2: I MAY LOVE SCIENCE, BUT THERE'S SOMETHING WRONG WITH ME

I was admitted to a prestigious Ivy League graduate school. I thought that by being admitted to Ivy U., I had proven myself. Everyone would treat me like a scientist. I began to work with Dr. A., who was young, enthusiastic, and liked to talk science with me. He showered me with positive feedback for even the simplest laboratory task and made me feel respected and even admired. But Dr. A. only worked in his lab late at night. During the day, I was the only woman in the lab besides the technician, who always worked with headphones on, in a laboratory of thirteen men (two visiting scientists, four postdocs, two graduate students, and four undergraduates as well as Dr. A. himself). The laboratory environment was quite different during the hours I regularly worked, and my colleagues did not welcome me.

Initially, I was eager to talk about science as much as possible, but I was continually snubbed, ignored, and/or treated patronizingly by lab members for my combined enthusiasm and lack of expertise. By the end of my second year, I avoided the lab as much as possible. Thus, I was simultaneously nerdy and not dedicated enough. I did not flirt, not being interested in sleeping with anyone in the lab, nor wishing to be accused of sleeping with anyone in the lab. Thus, I was snobbish and cold. The only person in the lab who would talk to me, claimed he was doing me a favor by telling me what people were saying. There was little I could do to remedy these perceptions of me. The plainer I dressed, the more frigid I was perceived to be; the less time I spent talking about science, the more obvious it was to my detractors that I was ignorant. If I tried to flirt I was indeed a slut and if I worked hard, it was obvious that I was trying to make up for my deficiencies.

Since I continued to get along well with Dr. A., despite my unhappy relations with members of his lab, the gossip circulated we were sleeping together. I began to take pains to not be seen interacting with him outside the lab, and our relationship was damaged as a result. When I explained my behavior to him, he told me he thought that my concerns were "asinine" but sadly also withdrew. Thus I was beset at every turn, yet I worried that I was being hypersensitive.

In my misery, I became involved in the graduate women's alliance, an openly feminist organization. In that context, I began to realize that being the only woman in the lab had something to do with my troubles. Without these women I never would have finished graduate school, because they helped me put my experiences into a coherent framework other than the only one that had occurred to me, which was that I was not cut out to be a scientist after all.

Four years later, however, I was no happier in the lab group. The technician had quit after her accusations of sexual harassment from someone in the lab went unresolved. Dr. A. had received a great job offer at a major midwestern university that included funding for all of us, so most of us moved. Two women graduate students had joined us, later to drop out of the lab and graduate school entirely. I remain the only woman ever to get a degree from that lab. The controversy around the sexual harassment accusation, the unhappiness of my women colleagues, and the move to another university all took their toll on me; but I stayed, and stayed, and stayed. I looked in the mirror one day and did not like what I saw: a calculating, hardened person. I began to think of abandoning my plans for a science career. Was the research I loved worth my sense of self?

PHASE 3: THE PERSONAL IS POLITICAL IS PROFESSIONAL

At this point, I sought out a woman mentor and feminist colleagues. Both provided critical support for my scientific career. Even though I was again outnumbered by men among my colleagues, there were many women with whom I could be completely open and my mentor, Dr. L., proved to be organized, kind, socially adept, brilliant, famous, and witty. She even had a Real Life outside the lab. I also had some supportive male colleagues inside and outside the lab, and a few even tolerated my openly feminist stance. Still, the pattern of harassment had not completely evaporated. There was a very unpleasant instance of inappropriate physical behavior by a senior colleague that resulted in a severe rift and subsequent period of isolation for me. There was yet another colleague, whom

I trusted, who did his best to convince me that I was not dedicated enough.

The feminist community in the area included someone in Women's Studies who was working with a group of feminist scientists. I looked her up, joined the group's seminars, and began to get a serious education in feminist theory and feminist science studies. Since that time, I've worked with a team who developed and taught a course in women in science and technology presented at feminist conferences. We have provided one another with support, encouragement, and friendship. Intellectually, I am more aware of the biases that my colleagues and myself bring to our science. I can analyze the results of my colleagues better for it, and when my gut contorts over some obfuscated gender-based assumption, I can articulate the problem clearly. I am now comfortable with the awareness that at first was so painful to me: science is, after all, a social enterprise, not an exercise practiced by disembodied brains.[6] But given that most of my colleagues are not comfortable with this idea, how do I behave as a scientist while remaining true to my beliefs?

PHASE 4: CLAIMING A POLITICAL STANCE

I am in phase four as I write this essay, since putting my ideas to paper for a feminist audience is itself a political act. However exhilarating it is to share my views with you, there may be costs since my colleagues are unlikely to endorse my account. In short, taking a step toward feminist community requires taking a step away from my scientific one. Because my work on the structure of the ovary in *Drosophila* could be appropriated for use in sex difference research, I find myself walking a tightrope between illuminating basics in female biology and contributing to essentialist, male-centered, sociobiological agendas. The persistent misreading of Bateman's work is a case in point. If the scientific community has focused on describing the male and the not-male, research on females could be seen as a corrective, a realignment of prevailing assumptions. Yet, an open discussion within science about the inadequacy of the male-centered model of evolution seems unlikely, at least in my field. A discussion about female biology that does not include a focus on sex differences, given the context, is unimaginable.

Some are arguing that the rigidly dichotomized heterosexual model of the natural world is inadequate and inaccurate. I agree, but at the same time, there are continuities among animals with ovaries that have a much overlooked contribution to make to medical knowledge. Can we foster the growth of knowledge about women's biologies without reinforcing sex difference arguments, especially given the masculinist culture of contemporary science? And if women are excluded/marginalized from science as researchers, and females are excluded/marginalized from science as subject matter, is any change in that culture possible? Given that this is going on in my field, is it also going on in other fields, particularly those that use animal models? I do not have any answers to the questions I have raised, but I hope that this article may serve as a starting point to a conversation in feminist science studies about the long shadow of androcentrism on both the climate and the construction of knowledge.

NOTES

1. For an overview of this work, see Wyer et al. 2000.
2. For a discussion of the varying visions of feminist science, see Harding 1991.
3. Extrapolation from flies to people is presented explicitly in most genetics textbooks: Atherley, Girton et al. 1999, 9; Griffiths, Gelbart et al. 1999, 10; Klug and Cummings 2000, with respect to behavior genetics, 672. However, rather than mentioning sex, it is generally assumed that data are universal for males and females.
4. For model organisms in general, see http://www.nih.gov/science/models/ index.html; for *Drosophila* in particular, see http://www.nih.gov/science/models/nmm/appb3.html.
5. For different perspectives on the value of feminism for science, see Fedigan 1997; and Hrdy 1999.
6. Most feminist theorists would take this for granted, but scientists are less willing to grasp its importance. For a debate about this topic, see Sokal 1996.

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CHAPTER 5

When Computers Were Women

Jennifer S. Light

J. Presper Eckert and John W. Mauchly, household names in the history of computing, developed America's first electronic computer, ENIAC [*Electronic Numerical Integrator and Computer. Ed.*], to automate ballistics computations during World War II. These two talented engineers dominate the story as it is usually told, but they hardly worked alone. Nearly two hundred young women, both civilian and military, worked on the project as human "computers," performing ballistics computations during the war. Six of them were selected to program a machine that, ironically, would take their name and replace them, a machine whose technical expertise would become vastly more celebrated than their own.[1]

The omission of women from the history of computer science perpetuates misconceptions of women as uninterested or incapable in the field. This article retells the history of ENIAC's "invention" with special focus on the female technicians whom existing computer histories have rendered invisible. In particular, it examines how the job of programmer, perceived in recent years as masculine work, originated as feminized clerical labor. The story presents an apparent paradox. It suggests that women were somehow hidden during this stage of computer history while the wartime popular press trumpeted just the opposite—that women were breaking into traditionally male occupations within science, technology, and engineering. A closer look at this literature explicates the paradox by revealing widespread ambivalence about women's work. While celebrating women's presence, wartime writing minimized the complexities of their actual work. While describing the difficulty of their tasks, it classified their occupations as sub-professional. While showcasing them in formerly male occupations, it celebrated their work for its femininity. Despite the complexities—and often pathbreaking aspects—of the work women performed, they rarely received credit for innovation or invention.

The story of ENIAC's female computers supports Ruth Milkman's thesis of an "idiom of sex-typing" during World War II—that the rationale explaining why women performed certain jobs contradicted the actual sexual division of labor.[2] Following her lead, I will compare the actual contributions of these women with their media image. Prewar labor patterns in scientific and clerical occupations significantly influenced the way women with mathematical training were assigned to jobs, what kinds of work they did, and how contemporary media regarded (or failed to regard) this work. This article suggests why previous accounts of computer history did not portray women as significant and argues for a reappraisal of their contributions.[3]

WOMEN IN WARTIME

Wartime literature characterized World War II as a momentous event in the history of women's employment. In 1943 *Wartime Opportunities for Women* proclaimed, "It's a Woman's World!"[4] Such accounts hailed unprecedented employment opportunities as men were recruited for combat positions. New military and civilian women's organizations such as the Army's Women's Auxiliary Army Corps (WAAC, converted to full military status in 1943 and renamed the Women's Army Corps [WAC]), the Navy's Women Accepted for Volunteer Emergency Service (WAVES), and the American Women's Voluntary Services (AWVS) channeled women into a variety of jobs. The press emphasized the role of machines in war and urged women with mechanical knowledge to "make use of it to the best possible purpose."[5] *Wartime Opportunities for Women* urged: "In this most technical of all wars, science in action is a prime necessity. Engineering is science in action. It takes what the creative mind behind pure science has to offer and builds toward a new engine, product or process."[6] According to the U.S. Department of Labor's Women's Bureau: "The need for women engineers and scientists is growing both in industry and government. . . . Women are being offered scientific and engineering jobs where formerly men were preferred. Now is the time to consider your job in science and engineering. There are no limitations on your opportunities. . . . In looking at the war job opportunities in science and engineering, you will find that the slogan there as elsewhere is 'WOMEN WANTED!' "[7]

A multiplicity of books and pamphlets published by the U.S. War Department and the Department of Labor, with such titles as *Women in War, American Women in Uniform, Back of the Fighting Front,* and *Wartime Opportunities for Women,* echoed this sentiment. Before World War II, women with college degrees in mathematics generally taught primary or secondary school. Occasionally they worked in clerical services as statistical clerks or human computers. The war changed job demands, and one women's college reported that every mathematics major had her choice of twenty-five jobs in industry or government.[8]

Yet, as Milkman suggests, more women in the labor market did not necessarily mean more equality with men. Sexual divisions of labor persisted during wartime. The geography of women's work settings changed, but the new technical positions did not extend up the job ladder. A widely held belief that female workers would be dismissed once male veterans returned from the war helps to explain the Women's Bureau acknowledgment that "except for Ph.D.'s, women trained in mathematics tend to be employed at the assistant level."[9] The War Department and the Department of Labor actively promoted women's breadth of opportunity yet in some areas explicitly defined which jobs were "open to women." Classified advertisements ran separate listings for "female help wanted" and "male help wanted."

WOMEN'S AMBIGUOUS ENTRY INTO COMPUTING

Women's role in the development of ENIAC offers an account of the feminization of one occupation, "ballistics computer," and both the creation of and gendering of another, "operator" (what we would now call programmer). Ballistics computation and programming lay at the intersection of scientific and clerical labor. Each required advanced mathematical training, yet each was categorized as clerical work. Such gendering of occupations had precedent. Since the late nineteenth century feminized jobs had developed in a number of sciences where women worked alongside men. Margaret Rossiter identifies several conditions that facilitated the growth of "women's work."[10] These include the rise of big science research projects, low budgets, an available pool of educated women, a lack of men, a woman who could act as an intermediary (such as a male scientist's wife), and a somewhat enlightened employer in a climate generally resistant to female employees entering traditionally male domains. Craving opportunities to use their skills, some women colluded with this sexual division of labor. Many did not aspire to professional employment at higher levels.[11]

Occupational feminization in the sciences fostered long-term invisibility. For example, beginning in the 1940s, laboratories hired women to examine the nuclear and particle tracks on photographic emulsions.[12] Until the 1950s, published copies of photographs that each woman scanned bore her name. Yet eventually the status of these women's work eroded. Later publications were subsumed under the name of the lab leader, inevitably a man, and publicity photographs rarely showcased women's contributions. Physicist Cecil Powell's request for "three more microscopes and three girls" suggests how invisibility and interchangeability went hand in hand.[13] In a number of laboratories, scientists described women not as individuals, but rather as a collective, defined by their lab leader ("Cecil's Beauty Chorus") or by their machines ("scanner girls"). Likewise in the ENIAC project, female operators are referred to as "[John] Holberton's group" or as "ENIAC girls." Technicians generally did not author papers or technical manuals. Nor did they acquire the coveted status symbols of scientists and engineers: publications, lectures, and membership in professional societies. Ultimately these women never got a public opportunity to display their technical knowledge, crucial for personal recognition and career advancement.

Wartime labor shortages stimulated women's entry into new occupations, and computing was no exception.[14] Ballistics computing, a man's job during World War I, was feminized by World War II. A memorandum from the Computing Group Organization and Practices at the National Advisory Committee for Aeronautics (NACA), dated 27 April 1942, explains how the NACA conceived the role of computers: "It is felt that enough greater return is obtained by freeing the engineers from calculating detail to overcome any increased expenses in the computers' salaries. The engineers admit themselves that the girl computers do the work more rapidly and accurately than they would. This is due in large measure to the feeling among the engineers that their college and industrial experience is being wasted and thwarted by mere repetitive calculation."[15]

Patterns of occupational segregation developed in selected industries and job categories newly opened to women.[16] Women hired as computers and clerks generally assisted men. Captain Herman Goldstine, an ENIAC project leader, served as liaison from the U.S. Army's Ballistic Research Laboratory (BRL) to the Moore School of Electrical Engineering at the University of Pennsylvania, which produced ENIAC, and director of computer training for BRL. He recalls that by World War II "there were a few men [computers] but only a few. Any able-bodied man was going to get taken up into the armed forces."[17] With feminization came a loss of technical status, since other men doing more "important" technical and classified work remained in noncombatant positions. Thus, the meaning of "wartime labor shortage" was circumscribed even as it came into being.

While college-educated engineers considered the task of computing too tedious for themselves, it was not too tedious for the college-educated women who made up the majority of computers.[18] These were not simply cases of women taking on men's tasks, but rather of the emergence of new job definitions in light of the female workforce.[19] Celebrations of women's wartime contributions thus rarely challenged gender roles. Rather, popular accounts portrayed civilian jobs for women as appropriately feminine, "domestic" work for the nation—despite the fact they were formerly done by men.[20]

The introduction of technology also facilitated women's entry into paid labor. Machines stimulated the reorganization of work processes, often leading to the creation of new occupations and the culling of older ones. In both clerical and factory work, introducing technology changed some jobs so that women performed slightly different tasks rather than substituting directly for men. Women's entry into the workforce was greatest in new occupations where they did not displace men.[21] Once a particular job was feminized this classification gathered momentum, often broadening to include other occupations.[22] By World War II, computing was feminized across a variety of fields, including engineering, architecture, ballistics, and the aircraft industry. The new machines, capable of replacing hundreds of human computers, required human intervention to set up mathematical problems. Without a gendered precedent, the job of computer operator, like the newly created jobs of "stenographer typist" and "scanning girl," became women's work. There is, of course, a fundamental difference between the human computer and the programmer who transfers this skill to an automated process. In the 1940s, the skill of transferring this information—what we now call programming—fit easily with notions about women's work. As an extension of the job of a human computer, this clerical task offered slightly higher status and higher pay than other kinds of clerical labor.[23]

FEMALE COMPUTERS AND ENIAC GIRLS

Like much of scientific research and development during World War II, the ENIAC was the offspring of a wartime alliance between a university (the University of Pennsylvania, specifically the Moore School of Electrical Engineering) and the U.S. armed forces, in this case the Army Proving Ground (APG) in Aberdeen, Maryland. The APG housed the army's Ballistic Research Laboratory (BRL), which produced range tables for gunners. During the war, BRL recruited approximately two hundred women to work as computers, hand-calculating firing tables for rockets and artillery shells. In 1940, when President Franklin D. Roosevelt declared a national emergency, BRL commandeered the Moore School's differential analyzer and began to move some of its work to the university.[24]

One of the first women the army hired to work at the Moore School was twenty-two-year-old Kathleen McNulty. She had graduated in 1942 from Chestnut Hill College, in Philadelphia, with one of the three math degrees awarded in her class. McNulty and her friend Frances Bilas answered an advertisement in a local paper that said Aberdeen was hiring mathematicians:

> I never heard of numerical integration. We had never done anything like that. Numerical integration is where you take, in this particular case . . . [the] path of a bullet from the time it leaves the muzzle of the gun until it reaches the ground. It is a very complex equation; it has about fifteen multiplications and a square root and I don't know what else. You have to find out where the bullet is every tenth of a second from the time it leaves the muzzle of the gun, and you have to take into

> account all the things that are going to affect the path of the bullet. The very first things that affect the path of the bullet [are] the speed at which it shoots out of the gun [the muzzle velocity], the angle at which it is shot out of the gun, and the size. That's all incorporated in a function which they give you—a [ballistic] coefficient.
>
> As the bullet travels through the air, before it reaches its highest point, it is constantly being pressed down by gravity. It is also being acted upon by air pressure, even by the temperature. As the bullet reached a certain muzzle velocity—usually a declining muzzle velocity, because a typical muzzle velocity would be 2,800 feet per second [fps]—when it got down to the point of 1,110 fps, the speed of sound, then it wobbled terribly. . . . So instead of computing now at a tenth of a second, you might have broken this down to one one hundredth of a second to very carefully calculate this path as it went through there. Then what you had to do, when you finished the whole calculation, you interpolated the values to find out what was the very highest point and where it hit the ground.[25]

The work required a high level of mathematical skill, which included solving nonlinear differential equations in several variables: "Every four lines we had to check our computations by something called Simpson's rule to prove that we were performing the functions correctly. All of it was done using numbers so that you kept constantly finding differences and correcting back."[26] Depending upon their method, the computers could calculate a trajectory in somewhere between twenty minutes and several days, using the differential analyzer, slide rules, and desktop commercial calculators.[27] Despite the complexities of preparing firing tables, in this feminized job category McNulty's appointment was rated at a subprofessional grade. The BRL also categorized women like Lila Todd, a computer supervisor when McNulty started work at the Moore School, as subprofessional.[28]

Herman Goldstine recalls that BRL hired female computers almost exclusively. At first, most women were recent college graduates in the Baltimore and Philadelphia area. Adele Goldstine, his wife and a senior computer, expanded recruiting to include colleges across the Northeast, but the project still needed more personnel.[29] In a short time, recalls Goldstine, "We used up all of the civil service women we could get our hands on."[30] A memo to University of Pennsylvania provost George McClelland from Harold Pender, dean of the Moore School, explained how BRL sought to remedy the situation: "Colonel Simon, Chief of the Ballistic Research Laboratory, has had a specially selected group of WACs assigned to the Laboratory. Although these women have been individually picked they are for the most part ready for training and are not trained persons who can enter fully into the Laboratory's work. . . . By consulting appropriate persons on the campus it appears that this can be carried out without interfering with any of the University's regular work. . . . Under the above circumstances it appears that the University's regular work will not be disturbed and at the same time we will have the opportunity to do a rather important service."[31] Pender's memo embodies a more widespread ambivalence about women's wartime contributions, particularly as members of the military. While "specially selected" for a "rather important" task these women were simultaneously "not trained persons" and could not enter "fully" into the BRL's work.

Colonel Simon assigned two groups of WACs to work as computers. One used desk calculators and the differential analyzer for practical work at the BRL, while the other studied mathematics for ballistics computations at the University of Pennsylvania. These two groups alternated monthly for eight months. The first WAC course started on 9 August 1943. According to reports in the *Daily Pennsylvanian,* the university's student newspaper, these women assimilated smoothly into campus life:

> The WACs at present stationed on the University campus are members of two groups alternating in a special course at the Moore School of Electrical Engineering, and were detached from the unit at Aberdeen Proving Ground, Maryland. At Aberdeen most of them were assigned as computers. The two sections, each of which numbers approximately thirty women, are commanded by second lieutenants and corporals. They are taking courses that are equivalent to the work of a college mathematics major. The results of these studies will later be used in ballistic work at the Ballistic Research Laboratory of the Army Ordnance Department. They are stationed at the Moore School of Electrical Engineering rather than at any other University school because of the large amount of work that the Moore School has done in collaboration with the Ballistic Research Laboratory. They are quartered in the fraternity house [Phi Kappa Sigma], messed in Sergeant Hall, and receive physical training at Bennett Hall. They are required to police their own rooms and be in bed at eleven forty-five P.M., with the exception of weekends. Reveille must be answered at 7:10 A.M.[32]

In this straightforward report, the student reporter neglects to mention the concurrent and widespread tensions surrounding WACs. Only a month earlier, on 1 July 1943, President Roosevelt had signed legislation converting the Women's Auxiliary Army Corps to full military status as the WAC. The conversion was scheduled for implementation by 1 October. According to WAC historian Mattie Treadwell, "The following ninety days of the summer of 1943, initially called The Conversion, were perhaps the busiest in the history of the Corps."[33]

While the article quoted several WACs commenting about their campus lives in a quite positive tone, Adele Goldstine, in an undated letter to a correspondent, reported, "Rumor hath it that the WACs (Sec. I) have been told that they're unloved by everybody including the ES&MWTesses. If it's true, I'm sorry to hear it because I'm afraid it will make our uphill fight steeper."[34] Her letter suggests that the women's presence on campus had become the "interference" and "disturbance" intimated by Simon's memo. Indeed, ambivalence about The Conversion had triggered slander campaigns against WACs from 1943. The cold reception of WAC volunteers was a product not only of news media but also of local gossip: "Resentment was expressed in towns where WACs were quartered, to the effect that they were spoiling the character of the town."[35] The WACs in Philadelphia may have experienced some of the more widespread hostility towards enlisted women.

Separated by skill level into two groups, the WACs at the Moore school had forty hours of classroom instruction per week. According to the syllabus, the course was designed to treat "in succinct form the mathematics which a person should have to work on physical problems such as those likely to be met in the Ballistic Research Laboratory."[36] The mathematics ranged from elementary algebra to simple differential equations. In addition, a unit on the use of calculating machines covered computation- and calculation-machine techniques, handling numerical data, organizing work for machine calculation, and using slide rules.

The instructors included three men (a Dr. Sohon, a Mr. Charp, and a Mr. Fliess) and nine women (Adele Goldstine, Mary Mauchly, Mildred Kramer, Alice Burks, a Mrs. Harris, a Miss Mott, a Miss Greene, a Mrs. Seeley, and a Mrs. Pritkin). Accounts of ENIAC that discuss the WAC course, such as Goldstine's book and the civilian women's own reflections, mention as instructors only three married women: Adele Goldstine, Mary Mauchly, wife of John Mauchly of the Moore School, and Mildred Kramer, wife of Samuel Noah Kramer, a professor of Assyriology at the University of Pennsylvania. Yet archival records show that this is not the full story.[37] Perhaps this oversight is consistent with a different trend Rossiter discusses—that more prominent women in science were often married to notable men, also often scientists. It is unclear whether Goldstine, Mauchly, and Kramer became "visible" because their husbands' visibility accorded them extra attention, because these men somehow facilitated their wives' careers, or because the women themselves campaigned for recognition.

"Thanks for the Memory," a song presumably written by several WACs, offers a playful account of their time at the Moore School:

> Of days way back when school
> Was just the daily rule
> When we just studied theories
> For fun and not as tools—thank you so much.
>
> Of lectures running late
> Of Math that's mixed with paint
> Of dainty slips that ride up hips
> And hair-do-ups that ain't—thank you so much.
>
> Many's the time that we fretted
> And many's the time that we sweated
> Over problems of Simpson and Weddle
> But we didn't care—for c'est la guerre!
>
> That Saturday always came
> And teach ran for her train
> If she didn't lam—like Mary's lamb
> Her pets to Moore School came—thank you so much.
>
> Machines that dance and dive
> Of numbers that can jive
> Of series that do leaps and bounds
> Until you lose the five—thank you so much.
>
> Of half-hour luncheon treks
> How we waited for our checks!
> Of assets, liabilities—
> Till all of us were wrecks—thank you too much.
>
> We squared and we cubed and we plotted
> And many lines drew and some dotted
> We've all developed a complex
> Over wine, sex, and f(x)
>
> Of private tête-à-têtes
> And talk about our dates
> And how we wish that teacher would oblige
> By coming late—thank you so much.

And so on through the night.[38]

Even as the WAC courses went on, Moore School engineers were designing a machine to automate the production of the same firing and bombing tables calculated by the human computers: the ENIAC. Engineers wanted answers faster than women could supply them using available technologies. Yet ENIAC couldn't do everything itself. Programming equations into the machine required human labor.[39] The eventual transfer of computing from human to machine led to shifting job definitions. A "computer" was a human being until approximately 1945. After that date the term referred to a machine, and the former human computers became "operators."[40]

Herman Goldstine recounts selecting the operators. At BRL, one group of women used desk calculators and another the differential analyzer. Selecting a subgroup from each, Goldstine "assigned six of the best computers to learn how to program the ENIAC and report to [John] Holberton," employed by the Army Ordnance Department to supervise civilians.[41] With no precedents from either sex, the creation and gendering of "computer operator" offers insight into how sexual divisions of labor gather momentum. Computing was a female job, and other female clerical workers operated business machines. So it was not unusual that in July 1945, women would migrate to a similar but new occupation. The six women—Kathleen McNulty, Frances Bilas, Betty Jean Jennings, Ruth Lichterman, Elizabeth Snyder, and Marlyn Wescoff—reported to the Moore School to learn to program the ENIAC.

The ENIAC project made a fundamental distinction between hardware and software: designing hardware was a man's job; programming was a woman's job. Each of these gendered parts of the project had its own clear status classification. Software, a secondary, clerical task, did not match the importance of constructing the ENIAC and getting it to work.[42] The female programmers carried out orders from male engineers and army officers. It was these engineers and officers, the theoreticians and managers, who received credit for invention. The U.S. Army's social caste system is historically based on European gentlemen's social codes.[43] As civil servants, the six women computers chosen to operate the ENIAC stood outside this system.

Yet if engineers originally conceived of the task of programming as merely clerical, it proved more complex. Under the direction of Herman and Adele Goldstine, the ENIAC operators studied the machine's circuitry, logic, physical structure, and operation. Kathleen McNulty described how their work overlapped with the construction of the ENIAC: "Somebody gave us a whole stack of blueprints, and these were the wiring diagrams for all the panels, and they said 'Here, figure out how the machine works and then figure out how to program it.' This was a little bit hard to do. So Dr. Burks at that time was one of the people assigned to explain to us how the various parts of the computer worked, how an accumulator worked. Well once you knew how an accumulator worked, you could pretty well be able to trace the other circuits for yourself and figure this thing out."[44]

Understanding the hardware was a process of learning by doing. By crawling around inside the massive frame, the women located burnt-out vacuum tubes, shorted connections, and other nonclerical bugs.[45] Betty Jean Jennings's description confirms the ingenuity required to program at the machine level and the kinds of tacit knowledge involved:

We spent much of our time at APG learning how to wire the control board for the various punch card machines: tabulator, sorter, reader, reproducer, and punch. As part of our training, we took apart and attempted to fully understand a fourth-order difference board that the APG people had developed for the tabulator. . . . Occasionally, the six of us programmers all got together to discuss how we thought the machine worked. If this sounds haphazard, it was. The biggest advantage of learning the ENIAC from the diagrams was that we began to understand what it could and what it could not do. As a result we could diagnose troubles almost down to the individual vacuum tube. Since we knew both the application and the machine, we learned to diagnose troubles as well as, if not better than, the engineer.[46]

Framing the ENIAC story as a case study of the mechanization of female labor, it would be hard to argue that de-skilling accompanied mechanization.[47] The idiom of sex-typing, which justified assigning women to software, contradicted the actual job, which required sophisticated familiarity with hardware. The six ENIAC operators understood not only the mathematics of computing but the machine itself. That project leaders and historians did not value their technical knowledge fits the scholarly perception of a contradiction between the work actually performed by women and the way others evaluate that work. In the words of Nina Lerman, "Gender plays a role in defining which activities can readily be labeled 'technological.' "[48]

Meanwhile, at the Los Alamos Scientific Laboratory in New Mexico, scientists were preparing a new thermonuclear weapon, the Super. Stanley Frankel and Nicholas Metropolis, two Los Alamos physicists, were working on a mathematical model that might help to determine the possibility of a thermonuclear explosion. John Von Neumann, a technical consultant, suggested that Los Alamos use ENIAC to calculate the Super's feasibility. Once Von Neumann told Herman Goldstine about this possible use, Herman and Adele invited Frankel and Metropolis to Philadelphia and offered them training on the ENIAC. When the two physicists arrived in Philadelphia in the summer of 1945, Adele Goldstine and the women operators explained how to use the machine. McNulty recalled that "We had barely begun to think that we had enough knowledge of the machine to program a trajectory, when we were told that two people were coming from Los Alamos to put a problem on the machine."[49] Despite such self-effacing comments, the operators demonstrated impressive mastery of the ENIAC during the collaboration with the Los Alamos physicists. By October, the two theoretical physicists had programmed their elaborate problem on huge sheets of paper. Then, the women programmed it into the machine, which no one had formally tested. As McNulty explained, "No one knew how many bad joints there were, and how many bad tubes there were, and so on."[50] The cooperative endeavor furthered the operators' intimate understanding of ENIAC as they pushed it to a new level of performance. Programming for Frankel and Metropolis took one million IBM punch cards, and the machine's limited memory forced the women to print out intermediate results before repunching new cards and submitting them to the machine. Within a month, the Los Alamos scientists had their answer—that there were several design flaws.[51]

The "ENIAC girls" turned their attention back to shell trajectory calculations and were still engaged on that project when the war ended. The ENIAC, designed and constructed in military secrecy, was prepared for public unveiling in early 1946. A press conference on 1 February and a formal dedication on 15 February each featured demonstrations of the machine's capabilities. According to Herman Goldstine, "The actual preparation of the problems put on at the demonstration was done by Adele Goldstine and me with some help on the simpler problems from John Holberton and his girls."[52] Indeed, Elizabeth Snyder and Betty Jean Jennings developed the demonstration trajectory program.[53] Although women played a key role in preparing the demonstrations, both for the press and for visitors to the laboratory, this information does not appear in official accounts of what took place.

CONTEMPORARY ACCOUNTS OF ENIAC

Social constructionist historians and sociologists of science take the position that scientists describing their experimental work do not characterize events as they actually happened.[54] Publicity for technical demonstrations is not so different. In presenting ENIAC to the public, engineers staged a well-rehearsed event. They cooperated with the War Department, which controlled representations of the project through frequent press releases to radio and newspapers.

It is a curious paradox that while the War Department urged women into military and civil service and fed the media uplifting stories about women's achievements during the war, its press releases about a critical project like the ENIAC do not mention the women who helped to make the machine run. War Department press releases characterize ENIAC as "designed and constructed for the Ordnance Department at the Moore School of Electrical Engineering of the University of Pennsylvania by a pioneering group of Moore School experts."[55] They list three individuals as "primarily responsible for the extremely difficult technical phases of work . . . Eckert—engineering and design; Mauchly—fundamental ideas, physics; Goldstine—mathematics, technical liaison."[56] The War Department's selective press releases highlighted certain individuals involved in the ENIAC project while omitting others, specifically the women operators. Because of these omissions the operators were neither interviewed nor offered the opportunity to participate in telling the ENIAC story. Newspaper accounts characterize ENIAC's ability to perform tasks as "intelligent" but the women doing the same computing tasks did not receive similar acclaim.[57] While the media publicly hailed hardware designers as having "fathered" the machine, they did not mention women's contributions. The difference in status between hardware and software illustrates another chapter in the story of women in the history of science and technology. The unmentioned computer technicians are reminiscent of Robert Boyle's "host of 'laborants,' 'operators,' 'assistants' and 'chemical servants' " whom Steven Shapin described as "invisible actors." Working three centuries earlier, their fate was the same: they "made the machines work, but they could not make knowledge."[58]

The *New York Times* of 15 February 1946 described Arthur Burks's public demonstration: "The ENIAC was then told to solve a difficult problem that would have required several weeks' work by a trained man. The ENIAC did it in exactly 15 seconds."[59] The "15 seconds" claim ignores the time women spent setting up each problem on the machine. Accompanying photographs of Eckert and Mauchly, the article reported that "the Eniac was invented and perfected by two young scientists of the [Moore] school, Dr. John William Mauchly, 38, a physicist and amateur meteorologist, and his associate, J. Presper Eckert Jr., 26, chief engineer on the project. Assistance was also given by many others at the school. . . . [The machine is] doing easily what had been done laboriously by many trained men. . . . Had it not been available the job would have kept busy 100 trained men for a whole year."[60] While this account alludes to the participation of many individuals other than Eckert and Mauchly, the hypothetical hundred are described as men. Why didn't the article report that the machine easily did calculations that would have kept one hundred trained women busy, since BRL and the Moore School hired women almost exclusively as computers? Even in an era when language defaulted to "he" in general descriptions, this omission is surprising, since the job of computer was widely regarded as women's work.[61] Women seem to have vanished from the ENIAC story, both in text and in photographs. One photograph accompanying the *New York Times* story foregrounds a man in uniform plugging wires into a machine. While the caption describes the "attendants preparing the machine to solve a hydrodynamical problem," the figures of two women in the background can be seen only by close scrutiny. Thus, the press conference and follow-up coverage rendered invisible both the skilled labor required to set up the demonstration and the gender of the skilled workers who did it.

The role of the War Department and media in shaping public discourse about the machine and its meaning is significant. Several potential opportunities for the women operators to get some public attention and credit for their work never materialized. For example, the publicity photograph of the ENIAC printed in the *New York Times* was among the most widely disseminated images of the machine. When it was published as an army recruitment advertisement, the women were cropped out.[62] This action is understandable, at one level, since the operators were all civilians. Yet given the important participation of WACs in closely related wartime work, it constituted another missed opportunity to give the women their due.

Archival records show that photographers came in to record the ENIAC and its engineers and operators at least twice. Neither visit resulted in any publicity for the women. On the first occasion, an anonymous photographer's pictures of the ENIAC group turned out poorly. Herman Goldstine wrote apologetically to Captain J. J. Power, Office of the Chief of Ordnance: "Dear John, I am returning herewith the photographs with sheets of suggested captions. As you can see from looking at these photographs, many of them are exceedingly poor, and, I think, unsuitable for publication."[63] Nonetheless, the captions for these unsuitable photographs are instructive:

> VIEW OF ONE SIDE OF THE ENIAC: Miss Frances Bilas (Philadelphia, Pa.) and Pfc. Homer W. Spence (Grand Rapids, Mich.) are setting program switches. Miss Bilas is an ENIAC operator in the employ of the Ballistic Research Laboratory, Aberdeen Proving Ground, Md., and Pfc. Spence is a maintenance engineer. . . .
>
> SETTING UP A PROBLEM ON THE ENIAC: Reading from left to right, Miss Akrevoe Kondopria (Philadelphia, Pa.) at an accumulator, Miss Betty Jennings (Stanbury, Mo.), Cpl. Irwin Goldstein (Brooklyn, NY) and Miss Ruth Lichterman (Rockaway, NY) standing at function tables. Miss Kondopria is a Moore School employee on the ENIAC project; Miss Jennings and Miss Lichterman are ENIAC operators employed by the Ballistic Research Laboratory, Aberdeen Proving Ground, Md., and Cpl. Goldstein is a maintenance engineer. . . .
>
> SETTING UP A PROBLEM ON THE ENIAC: Reading from left to right, Miss Betty Snyder (Narberth, Pa.), Miss Betty Jennings (Stanbury, Mo.), Miss Marlyn Wescoff (Philadelphia, Pa.) and Miss Ruth Lichterman (Rockaway, NY). Miss Snyder is setting program switches on an accumulator; Miss Jennings is setting up numbers to be remembered in the function table . . . Miss Wescoff and Miss Lichterman are working at the printer. . . . The function table which stores numerical data set up on its switches is seen at the right and its two control panels are behind Miss Frances Bilas (Philadelphia, Pa.) who is plugging a program cable in the master programmer. Miss Bilas is an ENIAC operator in the employ of the Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland.[64]

"Setting switches," "plugging cables," and "standing at function tables"—such captions understate the complexities of women's work. While two men appear alongside the operators, they are "maintenance engineers," occupational titles suggesting technical expertise.

The second photographer was Horace K. Woodward Jr., who wrote an article about ENIAC for *Science*. He wrote to Adele Goldstine: "Dear Mrs. Goldstine and other mENIACS, You will be perturbed to hear that the color flesh shots (oops, flAsh shots) that I was taking 1 Feb 46 turned out nicely. I hadn't intended them for publication but thought you folks might like them."[65] His article in *Science* carried no photographs of the women and made no reference to their existence.

More surprising still, the media reports did not highlight Adele Goldstine, despite her leadership position and her expertise in a technical realm that had not earlier existed for either sex.[66] An affidavit Adele

Goldstine submitted as testimony in Sperry Rand v. Bell Labs explains how she saw her own role: "I did much of the programming and the setting up of the ENIAC for the various problems performed on it while I was at the Moore School. I also assisted my husband in training Mr. Holberton and a group of girls to set up problems on the ENIAC. . . . I worked with Mr. Holberton and his group to program each problem which they put on the ENIAC up to and including the demonstration problems for the ENIAC dedication exercises."[67] Adele Goldstine and Moore School professor Harry Huskey were charged with producing an ENIAC operating manual, a complete technical report, and a maintenance manual.[68] Herman Goldstine explains: "The only persons who really had a completely detailed knowledge of how to program the ENIAC were my wife and me. Indeed, Adele Goldstine wrote the only manual on the operation of the machine. This book was the only thing available which contained all the material necessary to know how to program the ENIAC and indeed was its purpose."[69] In addition, he reports that his wife contributed heavily to a 1947 paper he coauthored with John Von Neumann, "Planning and Coding Problems for an Electronic Computing Instrument".[70]

It is an overstatement to say that female computers and operators were never covered in any media. A few articles mention them, as in this example:

> An initial group, consisting primarily of women college graduates, especially trained for work by the Moore School, began the work in ground gunfire, bombing and related ballistics studies immediately after Pearl Harbor, when the Aberdeen Proving Ground's Ballistic Research Laboratory broadened its program at the University.
>
> Forerunners of a group eventually numbering more than 100, they made use of the Moore School's differential analyzer, which is equally useful in the realm of ballistics and the solution of peacetime mathematical problems.
>
> Two other groups were organized later, under separate contracts, one of which was devoted to analysis of experimental rocket firing at Aberdeen, while the other assisted in the proving ground development of new shells and bombs.[71]

This recognition is quite different from the publicity accorded to male officers and engineers associated with the project.[72] The article cited here portrays the women as interchangeable. Even if it were too space-consuming to name each human computer, it is still notable that the article describes the women as being trained for work "by the Moore School" as opposed to "by Adele Goldstine" or by her many female colleagues.[73] That ENIAC's 1946 demonstration doubled as a vanishing act for its female participants fits neatly with postwar propaganda that as early as 1944 began redirecting women into more traditional female occupations or out of the paid labor force entirely.[74]

And what of the several years after World War II? While the Department of Labor acknowledged women's desire to stay on in paid employment its publications were not so optimistic.[75] An avalanche of materials urged women to leave work. A 1948 *Women's Bureau Bulletin* reported on the situation for women with mathematics education who sought paid work:

> Although, during the war, production firms and Government projects were important outlets for women trained in mathematics, the emphasis, following the end of hostilities, shifted back to the more usual channels. Teaching and employment with insurance and other business firms became the principal outlets for women college graduates with mathematical training. . . . Most of the wartime research projects sponsored by the Government were dropped after V-J day. In the few that continued, the small number of mathematical jobs were filled by the staffs

> of the institutions at which the research was being done and by men with mathematical skills who were being released from military service. The women's military services, which utilized women with mathematical training during the war, were reduced to very small staffs. . . . As women leave, men will be hired to replace them. . . . Although many women are continuing on their wartime mathematical jobs, it is difficult to say how much of the gain will be in terms of permanent opportunities for women.[76]

The Federal Bureau of Investigation dropped many of the women it had hired as cryptographers during the war. By 1946, the National Bureau of Standards had filled most of the vacancies on its computing staff with male veterans.[77] At the Ballistics Research Laboratory, an army memorandum detailed criteria for how individuals would be let go, with separate instructions for male officers and for WAC officers.[78] With this in mind, the absence of women from an October 1946 army recruitment ad makes sense. The "propaganda machine," as Herzenberg and Howes call it, that during the war had so successfully called women out of their homes, made a 180-degree turn, pushing many women back towards full-time domesticity.[79]

In the 1950s, new opportunities developed alongside continuing ambivalences about women's occupational roles. A 1956 U.S. Department of Labor report on employment opportunities for women mathematicians and statisticians is replete with examples of women's mathematical work—and the future need for women mathematicians—in a variety of fields including programming. Four "findings" appear as an executive summary:

1. More women mathematicians and statisticians are currently needed, and interesting jobs await those trained at the bachelor's degree as well as graduate levels.
2. Young women in high school should be encouraged to try mathematics and if they have the qualifications for success in mathematics and statistics should be encouraged to prepare for those fields; anticipated shortages make the long-run outlook exceptionally favorable.
3. Young women who combine the qualifications for teaching with ability in mathematics should be encouraged to teach, at least part time, since in teaching they can magnify their contribution to the Nation's progress.
4. Mature college women who have majored in mathematics, possess the personal qualifications for teaching, and have time available to work, should prepare themselves through refresher courses in mathematics and education for teaching positions, if the live in one of the many communities experiencing or anticipating a shortage of mathematics teachers.[80]

The report explores a wide range of career options, including programming and actuarial work. Yet as the patriotic rhetoric of service "to the Nation's progress" makes clear, the Department of Labor prioritized teaching as a career choice. Science and engineering had won the war, and now the developing baby boom predicted a growing demand for math teachers.

Despite such exhortations, some women never left computer programming. Fran Bilas, Kay McNulty, and Betty Snyder continued briefly with ENIAC when it moved to BRL in 1947; Ruth Lichterman stayed on for two years.[81] Other women joined the ENIAC at BRL following the war. Betty Snyder Holberton went on to program UNWAC and to write the first major software routine ever developed for automatic programming. She also collaborated on writing COBOL and FORTRAN with Grace Hopper, a key programmer of the Mark I. Hopper left active duty with the U.S. Navy as a lieutenant in 1946 but remained with the Navy reserves until 1966. From 1946 until it started running programs around 1951, the Electronic Computer Project at Princeton's Institute for Advanced Study employed mostly female programmers, who included Thelma Estrin, Hedi Selberg, Sonia Bargmann, and Margaret Lamb. Their accomplishments are future chapters for a history of computer programming.

CONCLUSION

The ENIAC story highlights several issues in the history and historiography of gender, technology, and labor. Major wars have unmistakable influences on gender relations and work, and those effects can be elusive and complex. Conflicts among representations of women's work in computing ensure work for the historian in distinguishing seeming gender changes from real ones. These conflicts and sometime contradictions lie at the heart of women's historical invisibility.

First, the variance between effusive wartime recruiting literature and historians' evaluations of women's actual opportunities is striking. Disputing the claims of propaganda, historians generally agree that during wartime women may have made some progress in expanding the varieties of work they could do. Yet rather than move up the ladder of success women's work appears to have added more rungs at the bottom. The narrative histories of the ENIAC since 1946 echo this finding. With few exceptions, they make the implicit or explicit assumption that, while women were involved, their participation was not sufficiently important to merit explication. Thus, this episode in the history and historiography of computing confirms Rossiter's "Matilda effect": individuals at the top of professional hierarchies receive repeated publicity and become part of historical records, while subordinates do not, and quickly drop from historical memory.[82]

A second conflicting representation concerns the actual work performed by women contrasted with how employers categorized this work. As this article shows, the evidence of ENIAC challenges the implicit assumption of computing historians that the low-status occupations of women meant that their work could not be innovative. Wartime propaganda proclaimed "no limitations on your opportunities," yet only certain jobs were open to women. However, it was within the confines of precisely such low-status occupational classifications that women engaged in unprecedented work. Looking behind media accounts and later narratives of the development of ENIAC to consider primary source accounts of the work women actually performed reveals how its low-status categorization clashed with the kinds of knowledge required. Finding this mismatch offers the possibility that, in their work as operators, women moving into stereotypical male domains played a subversive role, challenging the gender status quo before the war. According to this view, women's invisibility reflects deep-rooted ambivalences about the roles women professionals began to occupy in the labor force. These ambivalences permeated both power relationships in the workplace and media portrayals of women's contributions.

Third, portrayals of women's postwar fate continue the ambivalence that characterized their wartime work. Women were seen as meeting a crisis—but only a temporary one. One 1943 guide to managers explained: "Women can be trained to do any job you've got—but remember 'a woman is not a man;' A woman is a substitute—like plastic instead of metal."[83] Both postwar propaganda and historians characterize women as retreating to teaching and homemaking after the war, abandoning their gains. Yet a fair number did not leave the workforce, a fact that the

Department of Labor acknowledged even as it urged women toward teaching.[84]

The revised history of ENIAC presented here reveals that many of historians' questions about the history of computing reflect the unintentionally "male-centered terms" of history.[85] The result is a distorted history of technological development that has rendered women's contributions invisible and promoted a diminished view of women's capabilities in this field. These incomplete stories emphasize the notion that programming and coding are, and were, masculine activities. As computers saturate daily life, it becomes critical to write women back into the history they were always a part of, in action if not in memory.

NOTES

Light, Jennifer S. (1999). "When computers were women." *Technology and Culture,* 40(3), 455–483.

1. History has valued hardware over programming to such an extent that even the *IEEE Annals of the History of Computing* issue devoted to ENIAC's fiftieth anniversary barely mentioned these women's roles. See *IEEE Annals of the History of Computing* 18, no. 1 (1996). Instead, they were featured two issues later in a special issue on women in computing.
2. Ruth Milkman, *Gender at Work: The Dynamics of Job Segregation by Sex During World War II* (Chicago, 1987).
3. Two books currently offer some information on the participation of women in computer history: see Autumn Stanley, *Mothers and Daughters of Invention: Notes for a Revised History of Technology* (Metuchen, N.J., 1993), and Herman Goldstine, *The Computer from Pascal to Von Neumann* (Princeton, 1972). For recollections from women who worked on the ENIAC, see W. Barkley Fritz, "The Women of ENIAC," *IEEE Annals of the History of Computing* 18, no. 3 (1996): 13–28. Other histories tend to make passing references to the women and to show photographs of them without identifying them by name.
4. Evelyn Steele, *Wartime Opportunities for Women* (New York, 1943), preface. For an analysis of American mobilization propaganda directed at women, see Leila Rupp, *Mobilizing Women for War: German and American Propaganda,* 1939–1945 (Princeton, 1978).
5. Keith Ayling, *Calling All Women* (New York, 1942), 129.
6. Steele, 101.
7. Ibid., 99–100.
8. According to a *Women's Bureau Bulletin,* "A coeducational university, which before the war had few outlets for mathematics majors except in routine calculating jobs, found many attractive jobs available to mathematics majors during the war, mostly in Government-sponsored research. . . . There was a definite shift from the usual type of employment for mathematics majors in teaching and in clerical jobs in business firms to computing work in industry and on Government war projects." See United States Department of Labor, "The Outlook for Women in Mathematics and Statistics," *Women's Bureau Bulletin* 223–24 (1948): 3. According to this report, women comprised the majority of high-school mathematics teachers.
9. Ibid., 8. Margaret Rossiter, *Women Scientists in America: Before Affirmative Action, 1940–1972* (Baltimore, 1995), 13, confirms this practice more widely in the sciences. The few women who worked in supervisory roles generally supervised other women, a much less prestigious managerial role than supervising men. However, at the Work Project Administration's Mathematical Tables Project, women supervised male computers. See Denise W. Gürer, "women's Contributions to Early Computing at the National Bureau of Standards," *IEEE Annals of the History of Computing* 18, no. 3 (1996): 29–35. The War Department in 1942 classified all military occupational specialties as either suitable or unsuitable for women; all jobs involving supervision over men were automatically declared unsuitable. Public Law 110 also made explicit that women could not command men without intervention from the secretary of war; see Bettie Morden, *The Women's Army Corps, 1945–1978* (Washington, D.C., 1990), 14.
10. See Margaret Rossiter, *Women Scientists in America: Struggles and Strategies to 1940* (Baltimore, 1982), also *Women Scientists in America: Before Affirmative Action, 1940–1972.* In the 1982 volume, p. 55, Rossiter describes the late-nineteenth-century star counters in astronomical laboratories who performed computer work for male astronomers. The famed astronomer Maria Mitchell was employed as a computer for the U.S. Coast and Geodetic Survey in the late 1860s. The term computer, meaning "one who

computes," originally referred to the human who was assigned various mathematical calculations. Ute Hoffman dates the use of computer to the seventeenth century, when it was used in reference to men who tracked the course of time in their calendars. For decades the terms computer and calculator were interchangeable. In fact, early computers such as the ENIAC and Mark I were called electronic calculators. See Ute Hoffmann, "Opfer und Täterinnen: Frauen in der Computergeschichte," in *Micro Sisters: Digitalisierung des Alltags, Frauen und Computer,* ed. Ingrid Scholl and Ina Küller (Berlin, 1988). A number of other historians have documented women's work in other sciences. For example, Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago, 1997), discusses the work of women in high-energy physics laboratories, both those who counted flashes on the scintillator in Rutherford's laboratory and those who scanned the photographs from bubble-chamber experiments. Caroline Herzenberg and Ruth Howes, "Women of the Manhattan Project," *Technology Review* 8 (1993): 37, describe the work of women at Los Alamos, "some with degrees in mathematics and others with little technical background," who performed mathematical calculations for the design of the bomb. Amy Sue Bix, "Experiences and Voices of Eugenics Field-Workers: 'Women's Work' in Biology," *Social Studies of Science* 27 (1997): 625–68, reports the work of female field-workers at the Eugenics Record Office, who gathered data on individuals and families. In every case the work was subordinate to men's. See also Jane S. Wilson and Charlotte Serber, eds., *Standing By and Making Do: Women of Wartime Los Alamos* (Los Alamos, N.M., 1988).

11. See Rossiter, *Women Scientists in America* (both volumes). According to Herman Goldstine, it was the fact that women were not seeking career advancement that made them ideal workers: "In general women didn't get Ph.D.'s. You got awfully good women because they weren't breaking their backs to be smarter than the next guy." Herman Goldstine, interview by author, Philadelphia, 16 November 1994. Goldstine also noted that the few men he encountered working on programming rarely conceived of their jobs as permanent. Rather, they were steps on the way to something better. These jobs were "never careers for them, but a way of making money for a short time." Consequently, Goldstine observes, "Men in general were lousy—the brighter the man the less likely he was to be a good programmer. . . . The men we employed were almost all men who wanted Ph.D.'s in math or physics. This [hands-on work] was a bit distasteful. I think they viewed what they were doing as something they were not going to be doing for a career. If you take a woman like Hedi Selberg [a programmer at the Institute for Advanced Study Electronic Computer Project] she probably didn't want to sit around with the baby all the time."
12. Galison cites the invention and popularization of the term "scanner girl."
13. Ibid., 176.
14. For further discussion of prewar trends in hiring practices, see Lisa Fine, *The Souls of the Skyscraper: Female Clerical Workers in Chicago, 1870–1930* (Philadelphia, 1990), and Margery Davies, *Women's Place is at the Typewriter: Office Work and Office Workers, 1870–1930* (Philadelphia, 1982). See also Milkman (n. 2 above), chaps. 1–3.
15. Paul Ceruzzi, "When Computers Were Human," *Annals of the History of Computing* 13 (1991): 242.
16. Cf. Milkman, 49: "The boundaries between 'women's' and 'men's' work changed location, rather than being eliminated. . . . Rather than hiring women workers to fill openings as vacancies occurred, managers explicitly defined some war jobs as 'suitable' for women, and others as 'unsuitable,' guided by a hastily revised idiom of sex-typing that adapted prewar traditions to the special demands of the war emergency." Both Milkman and Fine discuss how gender-specific advertisements reflect the feminization of specific occupations. Fine offers an analysis of the shifting gender imagery of some clerical occupations. On this point, however, note that focusing on the industry's language about women (in this case, the stories about the biological capacities and natural implications or womanhood—or, by extension, on the advertising techniques used to create a gendered labor force) can confuse industry ideals with women's actual practice. As Milkman's notion of the idiom of sex-typing suggests, there is indeed a disjuncture between women's prescribed place and what women actually did. This disjuncture is central to women's invisibility in technological history.
17. Goldstine interview (n. 11 above). The domain's masculinity appears in the preface of a textbook on exterior ballistics: Office of the Chief of Ordnance *The Method of Numerical Integration in Exterior Ballistics: Ordnance Textbook* (Washington, D.C., 1921). "The names of the men who have contributed most to its [the text's] development, particularly Major Moulton and Professor

Bliss, are mentioned in various places in the text, and to whom the writer might appropriately make personal acknowledgement, would amount practically to an enumeration of all the officers, civilian investigators, and computers who have been connected with the work in ballistics in Washington and at the Aberdeen Proving Ground."

18. The heads of the computing groups were all college graduates, as were the majority of computers.
19. "The title 'engineering computer' was created for these women, since such work before the war was done by young, junior engineers as part of their induction training following graduation from an engineering college." U.S. Department of Labor, "Women in Architecture and Engineering," *Women's Bureau Bulletin* 223–25 (1948): 56. See Sharon Hartmann Strom, *Beyond the Typewriter: Gender, Class, and the Origins of Modern American Office Work, 1900–1930* (Urbana, Ill., 1992), for a discussion of similar circumstances within American businesses. To call a particular job "feminized" does not restrict it to women. Certainly there were some male computers and programmers. For a review of literature on gender and technology, see Nina Lerman, Arwen Palmer Mohun, and Ruth Oldenziel, "Versatile Tools: Gender Analysis and the History of Technology," *Technology and Culture* 38 (1997): 1–30.
20. The idiom of sex-typing made the sexual division of labor seem natural; differences in work capacity were considered biologically based. Evelyn Steele, editorial director of Vocational Guidance Research, writes, "It is generally agreed that women do well at painstaking, tedious work requiring patience and dexterity of the hands. The actual fact that women's fingers are more slender than men's makes a difference. Also, women adapt themselves to repetitive jobs requiring constant alertness, nimble fingers and tireless wrists. They have the ability to work to precise tolerances, can detect variations of ten-thousandths of an inch, [and] can make careful adjustments at high speed with great accuracy"; Steele (n. 4 above), 46. Women's strengths thus lay in performing repetitive, detailed, unskilled tasks. Such statements were not new. Arguments made in favor of women working as telephone operators were similar: "The work of successful telephone operating demanded just that particular dexterity, patience and forbearance possessed by the average woman in a degree superior to that of the opposite sex." Brenda Maddox, "Women and the Switchboard," in *The Social Impact of the Telephone,* ed. Ithiel de Sola Pool (Cambridge, Mass., 1977), 266. See also Fine (n. 14 above), chap. 4, "The Discourse on Fitness: Science and Symbols." For a discussion of women's wartime labor as portrayed in literature and advertising, see Charles Hannon, "'The Ballad of the Sad Cafe' and Other Stories of Women's Wartime Labor," *Genders* 23 (1996): 97–119.
21. For a further discussion of the prewar situation and the complex interaction between new technologies and the sexual division of labor, see Fine, also Davies (n. 14 above). Jobs with a more established tradition of male employment were less likely to become feminized before World War II. For example, while "clerk" and "bookkeeper" stayed largely male, feminization was more widespread in stenography because it had not been defined as male. See Milkman (n. 2 above), chap. 4. For further discussion of how new jobs were gendered, see Heidi Hartmann, Robert Kraut, and Louise Tilly, eds., *Computer Chips and Paper Clips: Technology and Women's Employment,* 2 vols. (Washington, D.C., 1986), vol. 1, chap. 2.
22. See Rossiter, *Women Scientists in America: Struggles and Strategies to 1940* (n. 10 above), and Milkman.
23. At the time, women were concentrated in clerical roles more than in any other occupation; they comprised 54 percent of all clerical workers in 1940 and 62 percent in 1950. U.S. Department of Labor, "Changes in Women's Occupations 1940–1950," *Women's Bureau Bulletin* 253 (1954): 37. Clerical work encompasses a broad range of jobs, including office machine operators. The Employment and Training Administration and U.S. Employment Service's *Dictionary of Occupational Titles* (Washington, D.C., 1939–41) classified computing-machine operator and calculating-machine operator as entry-level clerical occupations. For further discussion of the wide range of clerical jobs, see Strom (n. 19 above) and Fine. See also David Alan Grier, "The ENIAC, the Verb 'to program' and the Emergence of Digital Computers," *IEEE Annals of the History of Computing* 18, no. 1 (1996): 51–55.
24. It was part of a prior agreement with the Moore School that in times of national emergency the Aberdeen Proving Ground could commandeer the school's differential analyzer. Lydia Messer, oral history, interview by Cornelius Weygandt, 22 March 1988, University of Pennsylvania Archives, Philadelphia. Joel Shurkin, *Engines of the Mind* (New York, 1984), 119. BRL had apparently organized previous cooperative projects during World War I with the University of Pennsylvania.

The U.S. Army Ordnance Department's *Course in Exterior Ballistics: Ordnance Textbook* (Washington, D.C., 1921) credits H.H. Mitchell of the University of Pennsylvania as "Master Computer, who organized the range table computation work at Aberdeen." Before 1941, the Moore School also provided computers for BRL. Nancy Stern, *From ENIAC to UNIVAC: An Appraisal of the Eckert-Mauchly Computers* (Bedford, Mass., 1981), 10.

25. Shurkin, 128.
26. Shurkin, 127–28.
27. Stern, 13–14.
28. Not all women's jobs ranked lower or earned less than men's, but the history of female employment shows a persistent pattern into which the BRL's policies fit. For example, see Sharon Hartmann Strom, "'Machines Instead of Clerks': Technology and the Feminization of Bookkeeping, 1910–1950," in Hartmann, Kraut, and Tilly (n. 21 above), 2:63–97. See Fritz (n. 3 above) for women's accounts of the work they performed and H. Polachek, "Before the ENIAC," *IEEE Annals of the History of Computing* 19, no. 2 *(1997);* 25–30 for the complexities of computations for preparing firing tables.
29. Adele Goldstine received her bachelor's degree from Hunter College in 1941, then a master's from the University of Michigan in 1942. In 1942 she taught mathematics in the public school system in Philadelphia. From late 1943 to March 1946 she worked for the ENIAC project at the Moore School and spent part of 1944 at the Aberdeen Proving Ground. In 1948, she resumed graduate study at New York University. She became a consultant to the Atomic Energy Commission project effective 7 June 1947, working on making the ENIAC into a stored-program computer. Herman Goldstine recalls that "Los Alamos was the major user of the ENIAC so it was [John] Von Neumann [who was using it]. Adele was his assistant. I was also a consultant but she was doing the major part." Goldstine interview (n. 11 above).
30. Ibid.
31. Harold Pender to George McCelland, 23 July 1943, Information Files: World War II: WAC Training: Miscellaneous, University of Pennsylvania Archives.
32. *Daily Pennsylvanian,* 29 September 1943, untitled clipping in Information Files: World War II: WAC Training: Miscellaneous, University of Pennsylvania Archives. While women received instructions from civilians (not an unusual practice in the armed services), they were commanded by military second lieutenants and corporals. The WAC officer in charge of the detachment on campus was Lt. Mildred Fleming.
33. Mattie Treadwell, *United States Army in World War Two Special Series: The Women's Army Corps* (Washington, D.C., 1954), 221.
34. Adele Goldstine to J. G. Brainerd, n.d., "Monday Night," Information Files: World War II: WAC Training: Miscellaneous, University of Pennsylvania Archives. The ES&MWTesses were the women involved in the Engineering, Science, and Management War Training courses. J.G. Brainerd was a professor at the Moore School and liaison with U.S. Army Ordnance.
35. Helen Rogan, *Mixed Company: Women in the Modern Army* (New York, 1981), 41; Treadwell, chap. 4. Building on the work of historians such as Milkman (n. 2 above) and Fine (n. 14 above), who have analyzed the need for women in men's jobs to maintain femininity, Leisa Meyer has described the sexual politics of women's entrance into military service; see "Creating G.I. Jane: The Regulation of Sexuality and Sexual Behavior in the Women's Army Corps During World War Two," *Feminist Studies* 18 (1992) 581–601, and *Creating G.I. fane: Sexuality and Power in the Women's Army Corps during World War Two* (New York, 1996).
36. "Topics Included in the Engineering, Science, and Management War Training Courses for Members of the W.A.C, from Aberdeen Proving Ground," Information Files: World War II: WAC Training: Miscellaneous, University of Pennsylvania Archives. There was a second training course in 1945; Herman Goldstine Papers, American Philosophical Society Library, Philadelphia (hereinafter Goldstine Papers).
37. Goldstine, *The Computer from Pascal to Von Neumann* (n. 3 above), 134; Fritz (n. 2 above). The histories of other sciences, in both Britain and the United States, show scientists' wives filling a number of the more senior women's positions in science. For example, Cecil Powell's wife Isobel led the scanning girls in Powell's laboratory, and Janet Landis Alvarez, wife of Luis Alvarez, trained the women bubble-chamber scanners at Berkeley. Among the computers at NACA were a number of engineers' wives. At the Los Alamos Scientific Laboratory, John Von Neumann's second wife, Klara Dan Von Neumann, became a programmer and helped to program and code some of the largest programs of the 1950s. Also at Los Alamos were Kay Manley, wife of John Manley, and Mici Teller, wife of Edward Teller, who performed mathematical calculations for the design of the bomb. For further discussion of couples in the sciences, see Helena M. Pycior,

Nancy G. Slack, and Pnina G. Abir-Am, eds., *Creative Couples in the Sciences* (New Brunswick, N.J., 1996). According to Fritz, at least four computers married engineers at the Moore School after 1946. Frances Bilas married Homer Spence, Kathleen McNulty became Mauchly's second wife, and Elizabeth Snyder married John W. Holberton. According to Goldstine, Betty Jean Jennings (Bartik) married a Moore School engineer. Also at the Moore School were Eckert's first wife, a draftsman for the ENIAC project; Alice Burks, whose husband Arthur worked with Eckert and Mauchly on the ENIAC design; and Emma Lehmer, wife of Derrick Henry Lehmer, a computer and table compiler.

38. "Thanks for the Memory," presumably written by WACs at the Moore School, ca. 1943–44, Goldstine Papers.
39. In a retrospective analysis, Goldstine framed the computers' job as a prime candidate for mechanization due to its low skill: "Computing is thus subhuman in that it calls on very few of man's manifold abilities and yet is fundamental to many of his other activities, as Leibnitz so clearly perceived. This then is basically why computing was chosen as a human task to be mechanized"; Goldstine, *The Computer from Pascal to Von Neumann,* 343.
40. It is unclear exactly when this shift occurred. It was at least as early as February 1945, when George Stibbitz wrote in a report on relay computers for the National Defense Research Committee: "Human agents will be referred to as Operators' to distinguish them from 'computers' (machines)." Ceruzzi (n. 15 above), 240.
41. Goldstine interview (n. 11 above). Interestingly, Milkman (n. 2 above) has discussed how jobs perceived as feminine in some places were quintessentially masculine in others—often within the same industry. The idiom of sex-typing, while consistent in individual factories, often differed among factories manufacturing the same product. On the Mark II computer at the Navy's Dahlgrgn Proving Ground, for instance, operators were male. This area deserves further study.
42. The terms hard and soft, as used to describe gendered tasks, are significant. For the hard and soft sciences, hard mastery and soft mastery are binary distinctions in science and technology implying that the "hard" ways of knowing are men's domain; "soft" ways of knowing are more feminine. Goldstine, when interviewed, reported that he had resisted "there being a distinction" between hardware and software. He observed: "At the beginning, the hardware was the important thing, but as soon as you get beyond the bottleneck of making the computer," programming software became a new bottleneck. "They've automated the bejeezus out of making chips but not software." Ironically, by the time the process of making hardware was automated programming software had become a man's job and acquired higher status than it had had in the 1940s. See, for example, Phillip Kraft, "The Routinization of Computer Programming, "*Sociology of Work and Occupations 6* (1977): 139–55.
43. Jeanne Holm, *Women in the Military: An Unfinished Revolution,* rev. ed. (Novato, Calif., 1992), 73. Social mores, as well as a variety of rules and regulations, meant that women's qualifications had to surpass men's before they could compete for higher-level jobs within academia (including government-sponsored research) and industry. The army had higher selection criteria for female officers and enlisted personnel "than those for men in the same service" (p. 50). P.L. 110, the legislation converting the WAC to full military status, specified that "its commanding officer could never be promoted above the rank of colonel and its other officers above the rank of lieutenant colonel; its officers could never command men unless specifically ordered to do so by Army superiors" (Treadwell [n. 33 above], 220). Additionally, the War Department in 1943 set the ratio of female officers to enlisted women at one to twenty. Comparable figures for men were one to ten. Using the excuse of a surplus of male officers, it capped WAC officers by limiting entrants to the WAC Officer Candidate School but did not impose a similar limitation on male officers. None of the six women ENIAC operators held high status in academia or the military. Men at the Moore School who were not affiliated with the army, such as Harry Huskey or Arthur Burks, had visible academic appointments. See Rossiter, *Women Scientists in America: Before Affirmative Action, 1940–1972* (n. 9 above), for more on hierarchies, promotions, and payment in science.
44. Shurkin (n. 24 above), 188.
45. Kraft (n. 42 above), 141.
46. Fritz (n. 2 above), 19–20.
47. A number of historians have disputed de-skilling assumptions. For example, Sharon Hartmann Strom, "'Machines Instead of Clerks'" (n. 28 above), 64, describes in the case of bookkeeping machine operators how "workers continued to apply hidden skills of judgement and to integrate a number of tasks, particularly to jobs in the middle levels of bookkeeping, even though

these jobs required the use of machines." Fine (n. 14 above), 84, claims that the stenographer-typist's job was more challenging than the copyist's whom she replaced. For a review of literature on gender, mechanization, and de-skilling, see Nina Lerman, Arwen Palmer Mohum, and Ruth Oldenziel, "The Shoulders We Stand On and the View from Here: Historiography and Directions for Research," *Technology and Culture* 38 (1997): 9–30. See also Kenneth Lipartito, "When Women Were Switches: Technology, Work, and Gender in the Telephone Industry, 1890–1920," *American Historical Review 99* (1994): 1075–111.

48. Nina Lerman, "'Preparing for the Duties and Practical Business of Life': Technological Knowledge and Social Structure in Mid-19th-Century Philadelphia," *Technology and Culture* 38 (1997): 36. Judy Wajcman, *Feminism Confronts Technology* (University Park, Penn., 1991), 37, observes: "Definitions of skill can have more to do with ideological and social constructions than with technical competencies which are possessed by men and not by women."
49. Shurkin, 188.
50. Ibid., 189.
51. C. Dianne Martin, "ENIAC: Press Conference That Shook the World," *IEEE Technology and Society Magazine* 14, no. 4 (1995): 3–10. Because the problem was classified, the equations remained concealed.
52. Goldstine, *The Computer from Pascal to Von Neumann* (n. 3 above), 229. For details of the kinds of calculations performed using ENIAC, see Arthur W. Burks and Alice R. Burks, "The ENIAC: First General-Purpose Electronic Computer," *Annals of the History of Computing* 3 (1981): 310–89. The Burks were another significant husband and wife team, publishing their story together; Alice R. Burks and Arthur W. Burks, *The First Electronic Computer: The Atanasoff Story* (Ann Arbor, Mich., 1988).
53. Fritz (n. 2 above), 20–21. Goldstine recalled bringing Douglas Hartree, a physicist who had built a differential analyzer in Britain, to the United States for a visit. "I got Kay McNulty to be his programmer and she was good and intelligent. The girls soon branched off independently and it was during that period that my wife was making ENIAC into a stored program computer"; Goldstine interview (n. 11 above).
54. See, for example, Bruno Latour, *Science in Action* (Cambridge, 1987).
55. U.S. War Department, Bureau of Public Relations, "Ordnance Department Develops All-Electronic Calculating Machines," press release, February 1446, Goldstine Papers.
56. U.S. War Department, Bureau of Public Relations, "History of Development of Computing Devices," press release, 15–16 February 1946, Goldstine Papers.
57. For media characterizations of ENIAC, see C. Dianne Martin, "The Myth of the Awesome Thinking Machine," *Communications of the ACM* 36, no. 4 (1993): 125, 127; see also Martin, "ENIAC" (n. 51 above), 3–10. Like the laundry industry that made its employees invisible by publicizing the tireless machines, the ENIAC was portrayed as doing almost all of the work; Arwen Mohum, "Laundrymen Construct their World: Gender and the Transformation of a Domestic Task to an Industrial Process," *Technology and Culture* 38 (1997): 97–120.
58. Steven Shapin, "The House of Experiment in Seventeenth-Century England," *Isis 79* (1988): 395.
59. T. R. Kennedy, "Electronic Computer Flashes Answers, May Speed Engineering," *New York Times,* 15 February 1946.
60. Ibid.
61. The NACA memorandum (n. 15 above) specifically used she to describe the computers in its service. Women played salient roles in the demonstration of many domestic and business technologies, from sewing machines to typewriters to IBM office products, making their omission here all the more pointed.
62. See, for example, *Popular Science Monthly,* October 1946, 212.
63. Herman Goldstine to Captain J. J. Power, Office of the Chief of Ordnance 17 January 1946, Goldstine Papers.
64. ENIAC file appended to Goldstine to Power, 17 January 1946.
65. Horace K. Woodward Jr. to Adele Goldstine, 23 February 1946, Goldstine Papers.
66. While Adele Goldstine did not receive media acknowledgement, she clearly had some status among her colleagues at the Moore School as the only woman working on the machine's hardware. Initially, she oversaw Holberton. As head of the WAC course, despite her civilian status, she had frequent contact with top administrators at both the Moore School and the Aberdeen Proving Ground. In a publicity folder, biographical profiles on approximately a dozen staff members at the Moore School connected with the ENIAC include J. Presper Eckert, John W. Mauchly, Herman H. Goldstine, John G. Brainerd, Arthur Burks, Harry Huskey, Cpl. Irwin Goldstein, and Pfc. Spence. Adele Goldstine is the only woman included.

67. The affidavit is included in a letter from Harry Pugh, at Fish, Richardson, and Neave, to Herman Goldstine, 12 December 1961, Goldstine Papers.
68. Goldstine, *The Computer from Pascal to Von Neumann* (n. 3 above), 200.
69. Ibid., 330.
70. Ibid., 255 n. 4.
71. "Studies at Penn Aided Artillery," undated clipping from unidentified news paper, ENIAC Publicity Folder, Goldstine Papers.
72. See, for example, Allen Rose, "Lightning Strikes Mathematics," *Popular Science Monthly,* April 1946, 85, photo caption: ". . . Sharpless, of the Moore School of Engineering, sets a dial on the Eniac's initiating unit, which contains some of the master controls of the huge, complex mechanics. . . . Mr. Sharpless designed some Eniac equipment."
73. Bruno Latour and Steve Woolgar, in *Laboratory Life* (Beverley Hills, Calif., 1979), 219, point out that "a key feature of the hierarchy is the extent to which some people are regarded as replaceable."
74. Rupp (n. 4 above), 161.
75. Ibid., 161–62.
76. U.S. Department of Labor, "The Outlook for Women in Mathematics and Statistics" (n. 8 above), 9–11. See also U.S. Department of Labor, "A Preview as to Women Workers in Transition from War to Peace," *Women's Bureau Special Bulletin,* 1944; Rossiter, *Women Scientists in America: Before Affirmative Action, 1940–1972* (n. 9 above), chap. 2.
77. U.S. Department of Labor, "The Outlook for Women," 11.
78. Army Service Forces Office of the Chief of Ordnance, Washington, D.C., to personnel at BRL, 29 January 1946, Goldstine Papers.
79. Herzenberg and Howes (n. 10 above).
80. U.S. Department of Labor, "Employment Opportunities for Women Mathematicians and Statisticians," *Women's Bureau Bulletin* 262 (1956): vi.
81. For these women's later employment histories, see Fritz (n. 2 above), 17.
82. Margaret Rossiter, "The Matilda Effect in Science," *Social Studies of Science* 23 (1993): 325–41.
83. U.S. War Department, *You're Going to Hire Women,* booklet produced to persuade managers and supervisors to hire women, cited in Chester Gregory, *Women in Defense Work During World War II: An Analysis of the Labor Problem and Women's Rights* (New York, 1974), 12.
84. For example, the *Women's Bureau Bulletin* 262 (1956) features several pictures of women working with computers and mentions women coding and programming.
85. Gerda Lerner, "The Necessity of History," in *Why History Matters: Life and Thought* (New York, 1997), 119.

CHAPTER 6

The Intersection of Gender, Race and Cultural Boundaries, or Why Is Computer Science in Malaysia Dominated by Women?

Ulf Mellström

This paper addresses a familiar concern about the inclusion of women in science and engineering. Women's participation in science and engineering varies greatly around the globe, but there still seems to exist, as Lagesen (2005: 19) states, a lingering notion of an all-encompassing masculine culture of science and engineering transcending time and space. By using empirical data from Malaysia in the context of computer science, the paper aims to open a culturally situated analysis of the gendering of technology that undermines any notion of a global masculine culture of science and engineering, transcending cultural and national differences. Inspired by recent critical interventions and new analytical openings in gender and technology studies (Lagesen, 2005, 2007a,b; Bray, 2007; Landström, 2007; Rommes, 2007) the paper points to a western bias of gender and technology studies, and argues for cross-cultural work and intersectional understandings including race, class, age and sexuality. With the Malaysian case exemplifying the core of the argument, I argue that gender and technology studies needs to investigate configurations of masculinity and femininity in a cross-cultural perspective more thoroughly. The paper will focus on the relational dependence of male and female categorizations in gender relations, emphasizing that gender and technology relations are always deeply embedded in cultural contexts shaping the use, design and production of technologies and their co-production of gender and technology. In this it draws on earlier closely related work (Lagesen, 2005, 2007b), but it also differs in its aim to empirically analyse specific aspects of Malaysian culture, society and history in order to illustrate the cultural embeddedness of gender and technology relations. However, I shall use the Malaysian situation within computer science mainly as an example to highlight how an intersectional analysis takes form. Consequently, I shall not provide a full-fledged critical analysis of the multifaceted and divergent power dimensions of the Malaysian society.

The paper has three substantive parts. I will first present the so called 'woman problem' (Lagesen, 2005) in gender and technology studies and contemporary critical thought in feminist technology studies, invoking the theoretical tenets that possibly succeed this critique and how this feeds into the Malaysian situation. Second, I will present my case in terms of materials, methods, and the cultural specificities of computer science in Malaysia. Third, a discussion of the empirial case follows where I argue that the gender relations of computer in Malaysia has to be understood in regard to five strands of intersecting explanations: (1) quotas, ethnicity and gender; (2) a situated body politics; (3) technooptimism and techno-nationalism; (4) underachieving men; and (5) a critical mass of women and a shortage of computer professionals.

THE 'WOMAN PROBLEM' IN GENDER AND TECHNOLOGY STUDIES

The so-called 'woman problem', meaning the exclusion of women in science and engineering, has been thoroughly investigated in gender and technology studies. In spite of the fact that women are becoming the majority of the student population in most academic settings around the world, the relative absence of women from science and engineering remains puzzling (Quinn, 2003; Lagesen, 2005). This is especially so for information technology (IT). This relative lack of women is seen as a problem, while a predominance of men is regarded as the norm (Kramer & Lehman, 1990). Learning environments are not friendly to women (Siann, 1997; Henwood, 2000). Computer science technology grew out of the military, and its aura of combat and war has never attracted women (Mörtberg, 1987; Edwards, 1990). In reviewing the literature, Lagesen concludes that the 'woman problem' in computer science mainly has been understood as an issue of exclusion, and little is known about the women who actually decide to study computer science (Lagesen, 2005, 2007a; Sørensen, 2002). The history of gender and computer science as well as IT in general seem to follow a well-known pattern in western history of technology. Throughout this history, men have placed themselves in central positions, and technology has been associated with masculine values, whether it concerns machinery or digital technology (Cockburn, 1983, 1985; Hacker, 1989, 1990; Wajcman, 1991, 2000, 2004; Mellström, 1995, 2002, 2003, 2004; Oldenziel, 1999; Salminen-Karlsson, 1999; Faulkner, 2000, 2001; Lie, 2003).

In the western world, it seems that little has changed, as there are even fewer women in computer science today than in the late 1980s and the early 1990s (Salminen-Karlsson, 1999). However, when we look beyond the western world to developing countries such as Malaysia, we find that a growing number of studies present a more diversified picture (Kelkar et al., 2005; Ng & Mitter, 2005; Saloma-Akpedonu, 2005; Wajcman & Le, 2007). The position of women in the IT industry, and in new rapidly transforming digital economies in countries such as the Philippines, Brazil, Malaysia and Vietnam, gives hope for an emancipatory concern for a more gender balanced division of labour. In an investigation in the Philippines, Saloma Akpedonu (2005: 100) reports that women constitute 30% of the Philippine Computer Society and that their position in the IT industry has not resulted in a devaluation of status (see also Wajcman & Le, 2007: 6). In their study of the gender relations of software work in Vietnam, Wajcman and Le (2007: 23) conclude:

> Compared to women's employment in previous eras, IT work is a significant improvement. Women in the IT sector have higher levels of education and earn more than women working in agriculture or the service sector. The IT industry does provide a vehicle for women to gain both higher education and economic power in Vietnam.

The fact that in Malaysia, women's education, and their positions in computer science departments and software employment being equivalent to those of men, undoubtedly contributes to such relative optimism about gender and technology relations in developing countries. However, before moving to my case study, I shall briefly address some emergent epistemological dilemmas in gender and technology studies.

Analytical Openings in Gender and Technology Studies

Recently, critical interventions in the field of gender and technology studies have drawn attention to how heteronormative assumptions continue to pervade empirical research in feminist technology studies (Faulkner, 2001; Landström, 2007; Rommes, 2007). Landström (2007), in a critical re-reading of what she labels feminist constructivist technology studies, addresses the divide between theoretical discourse that collapses old deterministic gender binaries and empirical research that relapses into such binaries. In a similar vein, Els Rommes (2007: 13) shows how heterosexual imaginaries consistently work to reproduce gender dichotomies and hierarchies associated with computers, and how technologically competent women become masculinized in terms of various dimensions of heteronormativity. Closely associated with Landström's and Rommes' queer-theoretical interpretations are Vivian Lagesen's (2005, 2007a,b) and Francesca Bray's (2007) accounts of the 'black-boxing' of gender in gender and technology relations, where gender often is represented as stable while technology is treated as open to interpretative flexibility. Although Lagesen and Bray do not problematize the 'semiotics of heteronormativity' (Landström 2007: 14), they nevertheless point to a common analytical asymmetry in gender and technology studies (see also Gill & Grint, 1995; Landström, 2007). Another critique that has been addressed at various times in social studies of science and technology, as well as in feminist science and technology studies (MacKenzie & Wajcman 1999; Bray, 2007; Wajcman & Le, 2007), which now seems as pertinent as ever, is that there are so few studies of gender and technology relations in non-western societies. This new wave of critical thought in feminist technology studies, which originated from a combination of sexuality studies, material-semiotic and postcolonial approaches, points to a need to address a wider range of analytical themes in order to capture the inherent complexities and ambiguities of gender and technology relations.

My analysis follows up on this call to address non-western gender and technology relations. There are critical analytical consequences to such a focus. As Francesca Bray argues, 'in focusing so closely on the gender–technology nexus itself FTS [Feminist Technology Studies] sometimes neglects deeper-lying ideological dimensions within which any regime of truth concerning gender and technology must ultimately be understood' (Bray, 2007: 19). Consequently, furthering gender diversity in gender and technology studies opens up cross-cultural interventions, comparisons and intersectional understandings. A huge spectrum of variations in gender subjectivities in relation to artefacts and technology remains open to investigation, and its analysis can bring new perspectives to the field. This also implies that addressing the relative absence of gender and technology research on non-western contexts should introduce a wider range of cultural perspectives on the gender relations embedded in a diverse range of settings. Studies of gender and technology relations, and of technological change in general, consequently require attention as to how gender as well as class and race often instigate changes in the social and cultural balance in a nation such as Malaysia (see also Harding, 2006).

When reviewing existing literature in gender and technology studies, one conclusion seems to follow, which is that few studies go beyond treating gender and technology as analytical parameters, to include intersectional understandings of the gendering of technology. In other words, if, in theory, gender and technology are co-produced (Faulkner, 2000, 2001; Lagesen, 2005), so are ethnicity and technology, age and technology, sexuality and technology, and class and technology (see also MacKenzie & Wajcman, 1999: 25–26). Still, these latter dimensions of cross-cultural comparison and intersectional understanding are generally absent from STS research, and gender and technology studies particularly, with a few notable exceptions (for example, Traweek, 1988; Dyer, 1997; Verran, 1998, 1999; Traweek & Reid, 2000; Adams, 2002). My purpose in this paper is to invoke cross-cultural comparisons and intersectional readings, in general, and in reference to Malaysia in particular.

Consequently, my gender analysis is grounded in an intersectional understanding (Crenshaw, 1991; Peletz, 1996; Young, 1997; Yuval-Davis, 1997; Collins, 1998), where issues of inclusion and exclusion, power and powerlessness are to be understood by an integrative analysis of gender, race, age, class and nation. As the Malaysian feminists Cecilia Ng and Carol Yong (1995: 178) argue, '. . . while new technology skills are being polarized by gender, it also evident that women are entering computer professions in both the developed and developing countries, leading to a class polarization within the female labour force itself'. It is therefore also important to look at the wider picture in which technology, labour relations and education are embedded. From their Malaysian horizon Ng and Yong (1995: 178) also argue that, '[s]ince society is based on hierarchy, and technology is a medium of power, one needs to understand how power is negotiated'. In a postcolonial and multiethnic society such as Malaysia this also becomes highly pertinent, because class and ethnic differentials often are as important as gender differentials.

The Malaysian Case

The Malaysian case is interesting for gender and technology studies because of the gender ratios in the computer science and IT sectors of Malaysian industry. For instance, women constituted 65% of the students at the School of Computer Science at Universiti Sains Malaysia (USM), and 66% of the students in Computer Science and Information Technology at the University of Malaya, during the academic year 2001–2002 (Lagesen, 2005). As early as 1990/1991, women comprised 51% of the total student intake in computer-related courses in tertiary institutions (Ng & Yong, 1995). Among masters degree and PhD students at USM, more than 50% were women, and of the ten professors in the department in 2003, seven were women. There also is a high percentage of women in the professional information and computing technology (ICT) sector. Although Malaysian labour force statistics are not broken down according to specific educational attainments, women comprise 44% of professionals and 38.9% of technicians and associate professionals (ICT and computer science professionals are normally grouped in these statistical categories).

These gender distributions are noteworthy and very encouraging in terms of gender equality. They can be regarded as a possible catalyst for change in a developing country where substantial portions of the population currently are reworking their social and ethnic identities (Kahn & Loh, 1992; Gomes, 1994; Goh, 2002). However, according to Kahn and Loh (1992), this grand narrative of a specific Malaysian modernity must also be understood in terms of a fragmented society in which an emerging and substantial middle class is conspicuous. This emerging middle class is portrayed as the symbol and hope for moving beyond a tradition marked by sharp ethnic divides between the three major ethnic groups—Malays (58% of the population), Chinese (27%) and Indians (7%). Various political measures and programmes under the New Economic Policy

(NEP) of 1971, and the New Development Policy (NDP) of 1991, aim to strengthen the national economy and unite the country's ethnic groups. Still, a number of socioeconomic divides remain between the ethnic groups. This national balancing act associated with efforts to promote interracial harmony thus continues to pervade contemporary Malaysian society. In this balancing act, Chinese and Indian people have been marginalized, as non-Muslims, while the Malaysian state has been promoting a 'national culture' based on indigenous Malay culture, combined with a distinctly Islamic 'govermentalism' as a central feature (Nonini, 1998). 'Malayness' is usually identified in terms of language, religion and royalty (*bahasa, agama, raja*), and excludes anything 'Chinese' or 'Indian'. This balancing act is codified in the ethnic divisions and official politics between indigenous Malays (*bumiputeras*, meaning sons of the soil), and a number of other indigenous groups and *non-bumiputeras* (the Chinese and Indians).

The emerging middle class, united by relative prosperity and technical development, has the potential to be a powerful symbol and contravening force in the shaky ethnic and racial balance of contemporary Malaysian society. The supra-ethnic nationalist rhetorics and politics of the country have almost become an obsession with modernity through technological development. Technology in general and IT in particular hold highly positive connotations and are seen as major sources of individual and national empowerment. Malaysia, as a post-colonial society, has a nationalist politics that is most conspicuously manifested in Vision 2020 (Mahatmir, 1991), a plan for becoming a fully developed country—a K-society (knowledge society). This 'vision' is directed towards a 'common destiny' to be realized through technology and modernization. In such efforts to build and create a subjective sense of commitment, a 'common destiny' is crucial for constructing nationhood rather than emphasizing a common past (Yuval-Davis, 1997). The Malaysian State emphasizes this vision of national development as an effective way to generate a collective sense of belonging. Recurrent public campaigns such as the *Malaysia boleh* (Malaysia can, is able) crusade in the late 1990s and the beginning of 2000s persistently declare that a Pan-Malaysian identity (*Bangsa Melayu*, see Ariffin, 1993) is built through technology and development. This Pan-Malaysian identity is very much defined as a national body and is seen as primarily economic and technological, and looking towards the future (Williamson, 2002: 419). This new middle-class is sometimes described as the 'haves' in contrast to the 'haves-not' in the current programme of development. Access to a knowledge society and IT appears to be the dividing line between the 'haves' and 'have-nots' (Ng & Yong, 1995).

The relationship between gender (here almost exclusively defined as women) and technology in Malaysia has been investigated from different perspectives (Ong, 1987; Ng & Munro-Kua, 1994; Ng & Yong, 1995; Levidow, 1996; Ng & Mohamad, 1997; Ng & Thambiah, 1997; Ng, 1999; Lagesen, 2005; Ng & Mitter, 2005). As noted above, rapid industrialization, with an emphasis on IT and globalization are leading to class cleavages within the female labour force in Malaysia (Ng & Yong, 1995: 178). For instance, within the electronic components industry (semiconductors, disk drives, and so on) low-skilled technology employment is predominantly female and will probably remain so. But at the same time, leading female professionals within ICT-related businesses are occupying an impressively high proportion of executive positions (Ng & Yong, 1995: 178). These women are partaking in the formation of this imagined, as well real, formation of the new middle class that is supposedly leading the Malaysian nation into the future. Paradoxically, part of the explanation for why women have come to dominate computer science in Malaysia is due to the intensive ethnification of the Malaysian society and its consequences for higher education.

In sum, an important conclusion that can be drawn from research by feminists and other scholars studying the Malaysian context is that theories of gender identity should consider that ethnic and class inequalities often are as important as gender differentials. This means that we cannot focus on gender per se, but must also investigate the complex interrelationships of gender, class, age and ethnicity in a multi-ethnic society such as Malaysia. By taking my point of departure with an intersectional understanding of the highly complex multiethnic and stratified society of Malaysia, I shall explore how cultural dynamics influence and shape the construction of computer science as a woman-friendly technological field.

Materials and Methods

Material for this paper was collected through policy documents, newspaper articles, labour employment statistics and popular writings. It also draws upon a long-term study of gender in Malaysia that began in 1997 (Mellström, 2002, 2003, 2004). In 2003 and 2005, with the help of lecturers and professors at the Computer Science Department at Universiti Sains, Malaysia, in Penang, I conducted a questionnaire survey with 150 students in a computer science class.[1] I also completed ten interviews with students in the same class, and supplemented those data with periods of participant observation in lecture halls and on campus. I also had numerous informal conversations with lecturers, post-docs and professors at the department. Out of the 150 students, 111 (73%) were women and 39 (27%) were men. Of the women, 68 (45%) were Malay, 38 (25%) were Chinese, and five (3%) were Indian; of the men, 20 (13%) were Malay, 17 (11%) were Chinese, and two (<1%) were Indian. The students were taking a course in computer ethics, which might have meant that a disproportionally high number of women were taking the course, but according to lecturers from the department, the gender ratio was similar to that of most courses in the department.

The questionnaire focused on gender, ethnicity, family structure, educational choice and career plans. The ten interviews followed up on the themes laid out in the questionnaire, and enabled me to go into greater depth on the themes, and in a more reciprocal manner. I also attended computer science classes and talked to students in between lectures, at lunches, and at various social gatherings. I used English as the main language for the interviews, but occasionally also Hokkien, which is the dominant Chinese dialect of the island of Penang on the north-west coast of Malaysia.[2] In addition to these multifaceted data, I was able to draw upon previous experience with working in Malaysia to gain insight into gender and computer science. In what follows, I propose that a web of overlapping themes explains why computer science in Malaysia is dominated by women. My intersectional analyses draws on a form of methodological eclecticism that uses both historical and discursive understandings of Malaysian society, as well as individual and ethnographic evidence. Combining such diverse sources of data and interpretation produces a form of intersectional analysis that draws together a complex web of historical circumstances, contemporary politics and mundane realities.

QUOTAS, ETHNICITY AND GENDER

As noted earlier, the Malaysian nation is continuously balancing issues of interracial harmony and disruption as one of its fundamental socio-cultural dimensions. This tension is literally inscribed into this relatively new nation's history, present and future, not least in the division between bumiputeras and *non-bumiputeras*. This division, which sharply separated Chinese, Indians and Malays, was originally implemented by the British colonialists, but it was reinforced in the first period of self-government after independence in 1957. This reinforcement of ethnic politics eventually resulted in the racial riots and bloodshed of 13 May 1969, when nearly 200 people were killed. The memory of this traumatic event has still to be overcome, and has strong symbolic significance in today's politics, as it continually weighs against the Pan-Malaysian creation of *Bangsa Melayu*. Yet, after more than 30 years of economic progress and reform (associated with the NEP and NDP programmes), aimed at eliminating the identification of race with economic function, the inter-ethnic economic imbalance still prevails but is slowly being eased according to some analysts. The ethnic boundaries are, however, manifestly continuing in connection with the *bumiputera* policy through which Chinese and Indians are disfavoured on the grounds of race 'negative', while the *bumipetera's* (sons of the soil) special rights and privileges are inscribed in the Malaysian constitution. These rights and privileges for Malays and the Malay-related groups are inscribed in Articles 152 and 153 of the Constitution. The privileges range from quota protections in the fields of education, scholarship, employment, training, trade, business permits and so on. The *non-bumiputeras* sometimes refer to these privileges as *kulitification* (*kulit* is Malay for skin, race) in contrast to qualification. They were implemented under the NEP in 1971 and the New NDP in 1991. The special privileges defined in Article 153 of the Constitution are a highly sensitive issue. For example, in December 2000, a number of Chinese organizations asked for equal rights for all Malaysians, the so-called Suqiu claims, which upset many *bumiputeras* and especially the ruling United Malay National Organisation (UMNO) youth party, whose leaders claimed that the Chinese were trying to create racial unrest in the country. UMNO vice-president Tan Sri Muhyiddin Yassin said that if the Government accepted the Suqiu demands 'national integrity will suffer and Malaysia will not be able to maintain unity, economic growth and racial harmony enjoyed since independence' (*The Star,* 16 December 2000). The special privileges of Malays concerns a number of different societal areas, but in the area of higher education it means that the *bumiputeras* will be granted special scholarships, free tuition and special opportunities to study overseas, among other things. Until 2005, when students entered any of the state universities they were divided into *bumiputeras* and *non-bumiputeras*. The quota system guaranteed that at least 50% of the students would be *bumiputeras*. Since a much higher number of Chinese and Indian students generally apply to universities, the quota meant that the *non-bumiputeras* had to have much higher qualifications to get accepted. Since 2005, the system has been slightly changed, with a preparatory college year (matriculation) organized according to race-based principles. Currently, there are heated domestic debates about whether the bumiputera matriculation schools, which only Malay students attend, live up to the same standards as nonbumiputera colleges. Critics argue that this is not the case.

The race-based quota system for university admission is of special interest here, because the special *bumiputera* privileges have opened up an arena for Malay girls to study the classic masculine subject of computer science. They are favoured on the grounds of the race 'positive' policy, and granted student places that possibly would not have been open without the quota-system. As Lagesen (2005: 50) also notes, the proportion of Malay women in computer science courses and at the faculty level at University of Malaya (UM) was strongly influenced by the quota system. As other researchers also have shown (Ng & Thambiah, 1997; Ng, 1999; Luke, 2002; Lagesen, 2005), Chinese and Indian women and men feel discriminated against by the race-based politics. During my study, such feelings were articulated, off-the-record, by Chinese and Indian students, but never openly expressed in class or mentioned by senior academic staff. Viji, an Indian male student stated that he was considering doing his Master's in computer science in Chennai, India, because, he said: 'We non-*bumis* are not getting a fair chance in this system.' Other non-bumi students recurrently raised similar concerns in informal conversations. On an aggregate level, there also were indications that the system disfavours non-*bumis*, since the vast majority of the approximately 60,000 Malaysian students that study overseas each year are non-*bumiputeras* (Lee, 1999).[3]

In this perspective, race becomes a more pertinent and pervasive social category than gender, and it possibly and somewhat paradoxically operates more effectively to include women than many other inclusion strategies that have tried thus far. However, in this case, some Malay women are being positively affected by these inclusion measures, while Indian and Chinese women are not.

Situated Body Politics

The articulation of gender, race and class in Malaysia has long been informed by state policies, nationalist discourses and religious cosmology (Peletz, 1996). Nonini (1997, 1998, 1999) points to how Malaysian public spaces are divided by race, class and gender. Drawing on the work of Henri Lefebvre (1991) he shows how public spaces can be understood in relation to three forms of spatiality: spatial practices, representational space and representations of space. While trying to understand how women dominate computer science, I agree that it is crucial to understand the politics of space and bodies. According to Nonini (1998: 341), spatial practices are the embodied habitus and set of routines that people engage in when they move through and appropriate space as users. Representational space is affectively marked in perceptions and memories, and representations of space are visual signs such as maps. The concepts of spatial practice and representations of space are of foremost interest in the multiple ways. Race, class and gender mark out complex webs of spatial practices and representations of space. These fundamental social categories reach deeply into Malaysian society and continuously operate in public as well as in domestic spaces. The dynamics of a situated body politics then has to be understood in various intersections of these social categories. To a large extent, race can be understood as a hierarchy of bodies. This hierarchy also has become inextricably mixed with the hierarchy of masculinities (Connell, 2000) and femininities, as bodies are configured and governed by local gender discourses. The female majority in computer science in Malaysia is a case that illustrates this point.

The spatial associations of practices with computers, in relation to masculine and feminine bodies, made up a recurrent theme in the interviews and the survey (see also Lagesen, 2005, 2007b). One student, Zaharah, commented: 'IT for me is sitting in an office and do some business. Many men think that the IT-section is not real like engineering and media.' This remark is consistent with what almost all the interviewees said, which is that computer technology is spatially associated with indoor spaces and that such spaces are suitable for women. This also implies that the gendered associations with IT use and computer science, which are familiar from studies of western nations, are more or less absent in Malaysia. Lagesen (2007b) also points to the close spatial association between women, office technologies and indoor spaces. In other words, the spatial segregation of what counts as female and male spaces seems to precede the gender codification of the technology. None of the computer science students I interviewed associated computer technology with specific masculine characteristics. Instead, they expressed surprise that this was the case in western Europe. As Lagesen (2007b: 14–15) also notes, according to her interviewees, hardware network jobs make up a masculine field, because they are more mobile, physical, and involve outdoor exposure not suitable to women. Similiarly, interviewees in my study seemed to presuppose that practices with IT were associated with segregated gendered spaces.

However, when we examine how interviewees suppose that women's work is situated with indoor spaces symbolically connected to computing, it becomes clear that a division solely by gender would misrepresent the complex hierarchy of bodies. Computer science was generally perceived as a suitable occupation for women, irrespective of other social categories, while civil engineering was defined as a masculine field because of its outdoor working environment and exposure to critical situations, such as confronting foreign labourers at construction sites and the like (see also Lagesen, 2007b).[4] Still, it seems that even here there is a certain degree of interpretative flexibility with regard to what counts as 'genuinely' associated with gender, race and spatial practices. For instance, at a dam project on the northern part of the island, a Malay male engineer I interviewed said that women engineers are not fit for civil engineering (Mellström, 2003: 49). That is, they are not fit for outdoor work in the hot sun. At that very moment, I could not help wondering about the chief engineer of the big project, a woman from mainland China who evidently had spent uncountable hours in the hot sun managing the project. As if the Malay engineer had read my mind, he said: 'Well, I mean the female engineers in Malaysia. Engineers from China, they are different.' This is one of many examples in my materials of how gender intersects with race as a social category that operates through different spatial practices, and helps men to create spaces of their own and to keep women circumscribed by a situated body politics with its plethora of rules for what certain women can or cannot do.

Still, in the bigger picture it is no doubt the case that computer science as a professional activity and the IT sector as an industrial realm have opened up new emancipatory possibilities, spatial practices and representational spaces for Malaysian women, although it may not be the Cyberfeminist Utopia that one might have been hoped for (cf. Lagesen, 2007b). So, even though the liberating effect of the association between computing and femininity is regulated within a nationalist and local gender discourse, there is reason for relative optimism that computer science and IT work will offer major improvements for women in the Malaysian labour market, as the nation navigates between influences of 'western modernity' and an emerging Islamic modernity.

Techno-optimism and Emancipation

According to a number of Malaysianists, gender politics in Malaysia has almost always been superseded by race (see, for example, Ariffin, 1999; Mohamad, 2002). Given the totalizing ethnic politics pervading Malaysian society, gender is seldom problematized as a political issue. The women's movement in Malaysia has been organized either by women's groups entrenched in ethnic party politics, who often support ruling ethnic elites, or by feminist organizations organized through non-governmental organizations (NGOs) and located at universities. Maznah Mohamed (2002: 217) distinguishes between the women's movement at the centre and the one at the periphery, but also concludes that even if there is 'an ongoing contest between these two streams there has also been moments when they colluded for common gains'. Although there has never been a multicultural feminist movement in Malaysia, certain causes have united women from different ethnic groups. This was evident in the labour movement and the anti-colonial struggle for independence in the 1960s, as well as later in struggles against domestic violence and for opening up the labour market for women.

Of special interest here is how Malay women entered IT work and the related electronics industry. Before the influx of large-scale export-led industrialization in the 1970s and 1980s, few Malay women were part of the labour force, and Chinese women formed the majority of female industrial workers (Mohamed, 2002: 223). When Malaysia opened its economy to the global market in the 1970s, export-oriented industries were favoured such as textiles, garments and electronics. Hundreds of thousands of Malay women poured into the new job opportunities, partly because of their perceived dexterity and docility (Ong, 1987; Lie & Lund, 1994; Levidow, 1996).[5] The mass recruitment of this female, largely rural, labour force both changed the composition of the electronics industry sector and opened up a new labour market for Malay women, thus making the electronics industry symbolically associated with femininity. This influx opened up a representational space for women that was implicitly and explicitly referred to by students I interviewed whose mothers or female relatives had worked in the electronics industry. Penang (where USM is located) was a Free Trade Zone (FTZ) as early as the 1970s, and much of the early electronics industry in Malaysia was established there. Consequently, it was not surprising that as many as 34 (50%) of the Malay female students I interviewed had female relatives who had worked there in the electronics industry.[6] Judging from responses to the survey and interviews, even more of the respondents associated electronics in general, and IT work in particular, with the labour market for women. Farah, a 22-year-old Malay female student from the neighbouring state of Kedah said: 'Two of my aunts were working for AMD, two of my cousins for Sony. They all do assembly work. Many women in my *kampung* (village) are going to Penang for work in the factories.'

Consequently, this indicates that the conscious efforts to recruit low-paid women into this industrial sector early on also had some bearing on the symbolic effects and gender codification of IT work. As such, this sector came to represent a new industrial segment without the old gendered and racialized associations of the manufacturing industry associated with pre-independence days. In combination with a general undersupply of 'woman-power' in the electronics industry and a general shortage of computer professionals in the IT sector, there has been what one might term a *reversed symbolic gender appropriation* of the 'western' conception of computing, electronics, and IT work. However, as been pointed out earlier, the electronics industry and IT work have also fragmented the female labour force. On the one hand, there is the low-skilled technology employment, consistent with the image of the 'nimble-fingered' docile female worker, and on the other there is the female professional IT worker and academic. This is a highly charged and ambivalent symbolic space that nevertheless is occupied by a high proportion of women in a critically important industrial sector in a developing nation. This development in the IT sector also has had impact on wider gender relations in Malaysian society and has challenged notions of an all-encompassing global culture of masculine symbolism and values connected with computing.

Under-achieving Men

The fact that women dominate computer science and many other academic fields also goes hand in hand with a long-standing concern that Malay women outperform men in Malaysian academia, as well as in other areas of the society. This concern points directly to boys and men, and particularly Malay men. As has been publicly expressed for example by Dr Mahatmir Mohammad, former prime minister and Malaysia's dominant political figure for two decades, young Malay boys are not ambitious enough and Malay girls are more serious. In an interview in the English language newspaper *New Straits Times* (29 December 2000), Mahatmir stated:

> In the universities today, over 60% of the students, especially among the Malays, are women and they are studying serious subjects—engineering, science, management, etc, whereas the boys are studying simple subjects which they think they can pass, such as Bahasa Malaysia, Islamic Studies, and Social Sciences [sic!]. And when they come into the government, where are we going to place them? They don't have the capacity to deal with administration, while the women in the universities are studying serious subjects to become the lawyers, the doctors, the engineers, and the scientists. They have shown that they can deliver, for example, a woman who had been sent to space saying that she is highly qualified. So, do I send an unqualified man because he is a man? No, I think it is not the choice that I would choose.

What Mahatmir expresses is also mirrored in recurrent media debates and articulated at different levels of the Malaysian educational system, not least in the state university system. Such debates are part of the Malaysian public discourse as well as more local discussions. For example, a female professor and head of the computer science department at USM stressed that she would like to see more young Malay male students enrolled in her department but that: 'They don't seem motivated enough and we also have problems with young men dropping out of class.' She also mentioned that the department had launched recruitment campaigns at local matriculation colleges, '. . . but we mostly seem to reach the young girls'. The topic was recurrently discussed in the department, though differently, depending on who was interviewed and what their position was. A young lecturer in the department put the matter more bluntly when she said, '[b]oys are raised that way. Always used to roam around and not taking responsibility. I guess they think they will be head of families anyway so why bother?'

The arguments in this public debate often stress that Malay men must change their mind-sets and wake up to the new world of knowledge-society, modernity and technological development. Moreover, it is often argued, Malay men lag behind in the development of a pan-Malaysian identity: they remain stuck in their *kampung* mentalities and need to mature and take on more responsibility. Ironically, in this context, Malay men are often portrayed as effeminate, withdrawn from the challenge of forming the *Bangsa Melayu* character; not 'men' enough to cope with a modernity ruled by a globalized market economy, glossy consumerism and financial nationalism. Accordingly, the emergence of a new middle-class requires Malay men to conform to a Malaysian State doctrine for Islamic modernity which emphasizes *agama, raja* and *bahasa* on the one hand, and modernity through technological and financial nationalism, on the other. The combination of a heavily male-dominated bureaucratized Islam with a nationalism phrased in terms of modernity, is ultimately based on a global corporate masculinity (see Connell, 2000). However, although there is great variation, many Malay men consider this new masculinity to be 'foreign' or 'western': an import in which '[t]he "State" is metaphorized in men and the village in women, and the former seems more visible than the latter, and hence more powerful and dominant' (Karim, 1995: 26). This new conception of masculinity does not necessarily comply with a bilateral view of gender in which social relationships invert or blur older lines of hierarchy and difference, with their relationships of rank, class and gender. The particular bilateralism of gender relations typical of South-East Asia and Malay cultures, which emphasize lack of formality and avoidance of open conflict, tend to be overlooked by 'Eurocentric' analyses of power relations. As Errington (1990: 5) characterizes it: '[w]e also tend to identify "power" with activity, forcefulness, getting things done, instrumentality, and effectiveness brought about calculation of means to achieve goals'. The prevalent view in many parts of island South-East Asia, however, is that 'to exert force, to make explicit commands, or to engage in direct activity—in other words, to exert "power" in a Western sense—reveals a lack of spiritual power and effective potency, and consequently diminishes prestige' (Karim, 1995: 17). Apparently, this notion of power and manhood is rooted in the sphere of production, the public arena, presumably a hetero-normative masculinity based on successful participation in marketplace competition (Mellström, 1995: 170). Kimmel (1994: 122ff.) characterizes this as *marketplace manhood*, a kind of masculinity that sets standards for other men and women, and against which they are measured. It is a career-oriented form of masculinity in which members of an emerging middle class are supposed to become agents of change and to embody larger spatial-temporal patterns of modernity and globalized industry.

According to this conception of modern masculinity, traditional rural Malay men, accustomed to the confines of custom (*adat*) and a culture of kinship-relationality, become a problem. They are village (*kampung*) people, rejecting change, and their association with a *kampung* lifestyle is metaphorized as effeminate in this discourse of State and market forces. This 'foreign' and globalized notion of a competitive marketplace manhood based on an industrialized masculinity is thus dissonant with classical Malay notions of (hetero-normative) masculinity in which men's identities and senses of self are formed and based in kin and village relations. These older notions define masculinity, not by reference to men's roles or positions on the economy or political system, but in terms of relations (Peletz, 1996: 322ff.). Accordingly, masculinity is enacted through locally grounded social categories in daily life, such as brother, father, son, uncle, friend and husband. Certain male relational roles, such as father or husband, may have more dominant salience for the category of maleness than would any position in the so-called public arena (keeping in mind that such a 'westernized' concept may not apply here). A different form of hetero-normativity is at stake, as masculinity is performed or enacted through the interrelation between traditional social categories and in relation to reciprocal female roles. This is not say that masculinity stands on equal footing with femininity, but to suggest that classical Malay (hetero-normative) masculinity is a social category composed by a number of relational roles, and contrasts with notions of masculinity based on positions in the global political economy. To conclude, the traditional relational notion of masculinity opens space for women's participation in the positional sphere of a newly industrializing nation such as Malaysia. Many of the responses from young women in the survey and interviews resonated with their anticipated careers and future life-space, with regard to family, and more generally in relation to masculinity, class and race. The politics of space and, as shown earlier, the situated body politics in Malaysia, are of utmost importance for understanding how women have made, and can continue to make, headway into the traditional (in the west) masculine outpost of computer technology.

The Co-production of Computing and Gender in the Malaysian Context

In the final part of this paper I shall look more closely into the co-production of computing and women's work by following threads from the interviews and survey, which also link closely to previous research (for example, Ng & Yong, 1995; Ng & Mohamad, 1997; Ng & Thambiah, 1997; Margolis & Fischer, 2002; Lagesen, 2005, 2007a,b). In the upper echelon of women's IT work, where most of the interviewed students from computer classes at USM were likely to work in the future, it is evident that numbers and role models matter. As many as 51% of the female students answered that they thought that IT-related occupations, such as systems analyst, programmer, lecturer at the university and web designer, were available for them in the future because they had seen other women in those jobs. The students mentioned female lecturers at USM as sources of inspiration (see also Lagesen, 2005, 2007b) as well as alumni, who lectured in the department on a regular basis. Azlina, a third-year student recalled, 'this former USM student came the other week, and she was really successful, and everything she said was so inspiring.' In other words, the gender-balanced composition of computer science, combined with the number of women acting as role models through lecturing and working in IT businesses were very important for opening the representational space of computer science. As Lagesen (2007b: 87) also notes, this combination of factors opens up for a more flexible gender coding of computing and computer science. Whether or not such symbolic openness also caused significant change in the social environment was beyond the scope of this study, but since men have never dominated computer science in Malaysia, respondents such as Azlina had every reason to believe that the openness in the job marked would continue. Even to raise questions on this topic often elicited surprise, such as in a response from a second-year student, Maimunah's: 'Why do you ask that? Is that a problem?' When getting such responses I tried to explain that it is a problem in western countries, which was why I was interested in the Malaysian case. The theory that a critical mass of women is necessary to secure a gender-balanced recruitment is frequently discussed in research on women in science and engineering, and computer science in particular (Margolis & Fischer, 2002; Lagesen, 2007b). However, in academic as well as everyday discourse in computer science departments, it seems that gender-balance simply isn't discussed as a problem. A preoccupation with this question by western researchers like myself may strike respondents in this context as an imposition of an irrelevant concern. For them, race and class, interspersed with certain mainstreamed gendered questions, are more salient to concerns about exclusion and inclusion in higher education and professional careers. Gender is not necessarily articulated as an issue in the professional sphere, as long as it is confined to the familiar symbolic as well as material spaces that I discussed earlier. In other words, gender is much less salient in relation to race and class. More salient was the combination of relational and positional roles: how the 'public and private' interrelate, or how women in computer science and IT-related work manage their juxtaposition. Many of the female students in the survey and interviews spoke of how they try to balance family life with their careers.

For example, Atikah, a Malay female student said, '[I]t is very important that I can take care of my family first but also to make a career.' Most of the female students, irrespective of ethnicity, anticipated having full responsibility for their future families—with raising children and household work.[7] Male students did not anticipate such responsibility, although five men mentioned it. One conclusion that can be drawn from such responses is that the domestic division of labour was not questioned. Instead, female students anticipated having to find viable solutions for managing a professional career in combination with family responsibilities. As one of them, Zaharah phrased it: 'I will pursue a career until I reach 35, maybe 40, and then I will stay home with my children and husband.' Of course, such responses did not mean that the female students actually will withdraw from the labour market when it is time to raise a family, and many said that they chose to study computer science because it can be combined with family responsibilities. Apparently, they imagine this to be easier with academic jobs, as Atikah pointed out: 'I would not mind to become a lecturer because it seems to be flexible with family and everything' (see also Lagesen, 2005).

Employment statistics indicate[8] that there is a 'leaky-pipeline' effect in the ICT sector as a whole, which is segregated in terms of class and ethnic cleavages. Many urban women pursue full-time professional careers until about the age of 55 years (the average female retirement age in Malaysia). They seem to be able to do so in industry and academia without losing status and career opportunities, while women in many lower-income factory jobs tend to leave the workforce at an earlier age because of pregnancies, childcare and other family obligations. A tentative conclusion about this pattern is that opportunities for women mirror the structure of a fragmented labour force in a highly stratified multiracial society. In the science, engineering and technology sectors, race, class and age are no less crucial than gender is for determining career opportunities. The 'leaky pipeline' effect may be hard to trace for women in science, engineering and IT professions, but the it surely can be observed in particular industrial sectors in which many women move out from the labour market between the ages of 35 or 40 years, or never enter it at all, depending on their race and class.

Female students also expressed a great deal of ambivalence in their responses to my questions, probably reflecting the pressures that many young women in contemporary Malaysia experience. These pressures include social demands that arise from a gender paradigm that works in parallel with a positional labour market in which many young women perform especially well for many years. This labour market has been open to them, due to a combination of race-based quota-politics, a shortage of computer professionals, and a flexible gender codification system in computing. Nevertheless, this openness takes place in a social order that is still very much based in relational characteristics and the 'politics' of family relations.

This ambivalent situation has much to do with how the Malaysian state and nation are in the process of being metaphorized as an 'extended family' (see Yuval-Davis, 1997; Hylland-Eriksen, 1998). In a newly developing post-colonial nation, with a distinctive nationalist state politics building on *agama, raja* and *bahasa*, citizens are expected to share a familial sense of commitment to these values. Such commitment evidently varies among the different ethnic groups, due to past and present politics of inclusion and exclusion in the imagined community (Anderson, 1991). However, the very idea of an extended national 'family', implying paternalistic family and kinship relations at a national scale, also supports gender relations that are important for how computer science and IT work was viewed with techno-optimism by many Malay women in my survey and interviews. Their responses can be interpreted through this naturalized and 'primordial' image of the nation (Yuval-Davis, 1997: 15), in which educational and occupational choices are connected with and dependent upon familial relations. Two quotes illustrate this point: 'My parents want me to be someone that can give something in order to help my country' (Zanir, second-year student); 'I must help to develop our country to be more technologically advanced' (Azikah).

The desire to help build the nation is strikingly recurrent in responses from Malay female students, who speak of going into a field filled with promise for their own, their families', and their nation's future. They are very explicit about the responsibility they feel for their families and their country. In contrast to the Malay female students, Chinese and Indian students, irrespective of their gender, expressed very different views. Responses from male Malay students also differed, though to a lesser degree, from their female counterparts. Not surprisingly, the sense of communality is much less pronounced among the *non-bumiputeras*, as the very term suggests. Approximately one-half of the *non-bumiputera* students said that they planned to enter the transnational job market in countries such as the UK, USA, Australia, New Zealand and Japan. Such plans seemed realistic, given the large diaspora of Chinese and Indian populations from Malaysia (Mellström, 2003) that provide extensive transnational networks of mobility for students from those populations.

In sum, a number of factors are salient in the co-production of gender and computing in the Malaysian context. In my view, these factors point to the temporal and spatial variability and flexibility of gender and technology relations. To discern where, why and how technology is being symbolized and codified in Malaysia requires a thorough and locally informed gender analysis.

CONCLUSIONS

In this paper I referred to an eclectic set of data on women and computer science in Malaysia, and stressed the importance of investigating how gender and technology relations are embedded in specific cultural contexts. With the aim of opening up gender and technology studies to cross-cultural comparisons and intersectional analyses, I took up a familiar concern with the representation of women in science and engineering, and examined a case in which women dominate a field—computer science—that in western countries is predominantly a male domain. Inspired by recent critical interventions in feminist technology studies, I argue that gender and technology studies need to pay more attention to culturally situated analyses that bring local gender discourses into the picture. Computing and computer science are numerically dominated by men and symbolically charged with masculinity in many western countries, but in Malaysia they are situated within local gender discourses that change the polarity of the 'charge'. It is thus crucial to investigate relational aspects of gender, including positional relations of women and men with other relevant social categories intersecting and shaping gender relations. I hope this paper has demonstrated why it is of crucial importance to situate men, power and technology in such local contexts. I also addressed a form of analytical asymmetry that characterizes the process of co-production thematic to gender and technology studies, by discussing a case in which particular practices that dictate a priori which occupational and technological spaces are appropriate for specific gender categories. Accordingly, this paper casts doubt upon the notion that an all-encompassing masculine culture of science and engineering transcends time and space. It also offers a critique of a western bias of gender and technology studies, which can lead to context-insensitive analyses of the cultural situatedness of gender and technology relations.

NOTES

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1. I have elaborated elsewhere (Mellström, 2009) on the survey results of this research. In this paper I am rather concerned with general theoretical arguments.
2. A dialect I have mastered to a certain degree, because of earlier anthropological fieldwork in Penang (Mellström, 2003).
3. Available at http://aei.dest.gov.au/AEI/PublicationsAndResearch/MarketDataSnapshots/MDS_No05_Mal_pdf.pdf (accessed 6 December 2008).
4. This account reflects the xenophobic characterizations of foreign guest workers in Malaysian media, 'aliens' as they sometimes are called (*The Malaysian Daily, The Star*, 14 January 2000).
5. From 1970 to 1980, female workers in the manufacturing sector increased from about 70,000 to about 300,000 (Mohamad, 2002: 223n. 5)
6. Many of the students are locally recruited, meaning that they come from nearby northern states of Malaysia, such as Penang, Perlis, Kedah or Perak. A 'relative' can also mean a person in the extended family, and generally Malay families are large.
7. This category made up 73% of the female students.
8. In the Malaysian labour force, participation rates vary by sex and age group. We can see that in the age group 25–34 years, men comprise 97.2% and women 61.6%; in age group 35–44 years, it is 98.3% and 52.1%, respectively; and in the 45–54 year group, it is 94.7% and 44.5%, respectively. This fluctuates considerably, however, depending on the industrial sector, occupation and educational diplomas in question. In the upper and high-income branch of the ICT sector, the effect seems less pronounced, according to the lecturers and professors at USM that I interviewed. However, there are no available data to confirm this assessment. (Source: Labour Force Survey Report, First Quarter 2007, Malaysia, Series No. 10, No. 2/2007, August 2007, Department of Statistics.)

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CHAPTER 7

Interdisciplinary Approaches to Achieving Gendered Innovations in Science, Medicine, and Engineering[1]

Londa Schiebinger and Martina Schraudner

Gendered innovation uses gender as a dimension of quality in research process and in the transfer of ideas to markets. It introduces new analytical perspectives for considering the role of gender/sex similarities/differences as determinants of outcomes. To better understand gendered innovations, we distinguish three approaches taken by policy makers, institutional administrators, and scientists and engineers over the past three decades (Schiebinger 1999; 2008). The first focuses on programmes designed to increase women's participation. The second approach seeks to increase women's participation by transforming research institutions. The third focuses on overcoming gender bias in science and technology by designing gender analysis into all phases of basic and applied research—from setting priorities, to funding decisions, to establishing project objectives and methodologies, to data gathering, to evaluating results, and transferring ideas to markets. All three approaches are necessary for gendered innovations: it is important to point out, however, that increasing women's participation in science and engineering will not be successful without restructuring institutions and incorporating gender analysis into research.

The ultimate goal of gendered innovations is to enhance scientific and technological excellence. Research must 'control' for sex and gender. Sex and gender analysis act as yet further controls—one set among many standard methodologies—that serve to provide critical rigour in science. Gendered innovations also seek to create gender excellence; that is to say, to build inclusive scientific communities where men and women share equally at all levels in decision making, policy, and defining and carrying out research. Gendered innovations seek: 1) to create gender equality; 2) to enhance creativity; 3) to stimulate economic and technological development (or business innovation); 4) to make research more responsive to society. Innovation is what makes the world tick. Including gender analysis in science, medicine, and engineering can spark creativity by offering new perspectives, posing new questions, and opening new areas to research.

FIXING THE NUMBERS OF WOMEN IN SCIENCE, MEDICINE, AND ENGINEERING

The first and most straightforward approach to gendered innovations focuses on programmes to increase the participation of women in science, medicine, and engineering. The rationale is that the dearth of women scientists and engineers is a 'pipeline' problem and that more women need to be trained in technical fields.

Efforts in this area began in the 1980s as national governments and international agencies began collecting sex-disaggregated data to monitor women's participation. In 1982, the US National Science Foundation (NSF) published the first congressionally mandated report, *Women and Minorities in Science and Engineering* (NSF 1982). In 2003, the European Commission's Directorate-General (DG) for Research & Innovation published its first *She Figures,* reporting trends in women's participation across EU member states (European Commission 2003a).

In 1989, the US NSF established a Task Force on Programs for Women which sought to support women's careers in science and engineering by increasing women's research funding, teaching women negotiation skills, and setting up mentoring networks—or, more generally, making women more competitive in the scientific workplace (Rosser 2008). The European Commission recommended similar measures in its 2000 European Technology Assessment Network (ETAN) report, issued by the Helsinki group (ETAN 2000). This first approach seeks to increase women's participation by supporting women's education and careers. While critically important, this approach has also been criticized for 'fixing the women'. The implicit assumption is that science, medicine, and technology institutions and research are gender neutral. Consequently, this approach fails to look beyond women's careers to the need to reform scientific institutions and research methods. Achieving gender equality requires examining gendered divisions of labour in society at large and in science in particular, as well as considering how research is conceptualized and carried out.

FIXING THE INSTITUTIONS: TRANSFORMING STRUCTURES AND REMOVING BARRIERS

Despite claims to objectivity and value-neutrality, academic institutions have identifiable cultures that have developed over time—and, historically, in the absence of women (Hopkins 2006, 16; Margolis and Fisher 2002; Rosser 1994; Schiebinger 1989). To the extent that Western-style science has been replicated around the world, institutional structures, cultural stereotypes, and divisions of labour disadvantage women's participation. The second general approach taken by government policy makers and academic administrators seeks to increase gender equality by transforming research institutions. Beginning in 1993, the US NSF implemented programmes designed to create 'positive and permanent changes in academic, social, and scientific climates: in classrooms, laboratories, departments, institutions and organisations' (Rosser 2008).

The NSF's robust ADVANCE programme, launched in 2001, has made the US a global leader in institutional transformation. This model programme assists institutions (not individuals) in implementing structural changes to improve women and underrepresented minorities' success in science and engineering. Institutional reform ranges from counteracting subtle gender and ethnic bias in hiring and promotion practices to restructuring work/life balance by offering parental leave, supporting dual careers as well as child- and elder-care, and allowing for career breaks (NSFa; NSFb; Lavaque-Manty and Stewart 2008, 165–81; Schiebinger *et al.* 2008).

In 2010, the European Commission also moved to the institutional level, funding projects that encourage research organizations and universities to implement multi-year action plans to address institutional barriers, such as recruitment, promotion, retention policies and practices, management and research assessment standards, and policies for dual-career couples and career breaks (European Commission 2010b). In Germany, universities have agreed to increase substantially the number of women leaders in decision-making positions by the year 2013 (Deutsche Forschungsgemeinschaft).

Much remains to be done to restructure research and educational institutions to achieve gender equality. The goals here is to create conditions that allow both men and women's careers to flourish—conditions that allow all faculty members to achieve at the highest level.

This second policy approach focuses on institutional reform while often assuming that what goes on inside institutions—basic and applied research—is gender neutral. Restructuring institutions is important, but must be supplemented by efforts to eliminate gender bias from research and design. Change needs to come also at a third level: gendered innovations in scientific knowledge and technology design.

FIXING THE KNOWLEDGE: ENHANCING EXCELLENCE BY MAINSTREAMING GENDER ANALYSIS INTO BASIC AND APPLIED RESEARCH

Western science—its methods, techniques, and epistemologies—is commonly celebrated for producing objective and universal knowledge, transcending cultural restraints. With respect to gender, ethnicity, and much else, however, science is not value-neutral. Research has documented how gender inequalities, built into society and research institutions, have influenced science, medicine, and technology (Institute of Medicine 2010; Klinge 2010; Wajcman 2007; Biihrer and Schraudner 2006; Faulkner 2006; Schiebinger 1993; Harding 1991). Gender bias in research limits scientific creativity, excellence, and benefits to society. Gender bias in research can also be expensive: Between 1997 and 2000, 10 drugs were withdrawn from the United States market because of life-threatening health effects—four of these were more dangerous to women. Part of the problem is that preclinical research uses primarily male animals (Beery and Zucker 2011; Wald and Wu 2010; Zucker and Beery 2010; US GAO 2001).

The global leader in terms of this policy approach is the European Commission's DG Research & Innovation. In the 6th EU Framework Programme (FP6, 2002–2006), the DG Research & Innovation implemented its cutting-edge policy requiring that grantees applying for the largest grants (the Integrated Projects and Networks of Excellence grants) include a 'gender dimension' in research. As stated in the call for proposals, research design must specify 'whether, and in what sense, sex and gender are relevant in the objectives and the methodology of the project' (European Commission 2003b).

The EU, however, scaled back its innovative research requirement in the FP7 (2007–2013) because few researchers understood how to addressing gender in research (CSES 2009). Where do other granting agencies stand on this issue? The DG Research & Innovation is one of the few research organizations that requires grantees to address gender analysis in applications for all fields, although several European countries also include this as part of their national science policies—see, for example, Norway (Research Council of Norway)[2] and Spain (Sanchez de Madariaga 2011). The US NSF currently has no programmes that address these issues. Most recently, the Bill and Melinda Gates Foundation has committed to including gender analysis in their agricultural grants (Gates Foundation).

Policies requiring researchers to integrate gender analysis into research are more common in health research organizations.

Since 1993, the US National Institutes of Health has required researchers to reconceptualize medical research to include women and minorities in federally-funded research, though this has not been rigorously enforced (NIH 1993). The World Health Organisation mainstreams gender analysis into all 'research, policies, programmes, projects, and initiatives' (WHO 2002). The Canadian Institutes of Health Research has committed to 'Integrating Sex and Gender into Health Research' (CIHR 2003). In Europe, Sweden's Karolinska Institute and Germany's Charite Universitatsmedizin have both created centres for gender medicine that promote sex and gender analysis in basic and clinical health research (Haafkens and Klinge 2007).

Gender mainstreaming, adopted by the United Nations Fourth World Conference on Women in Beijing (1995), entails the systematic integration of gender equality into all systems and structures, policies, programmes, processes and projects, into ways of seeing and doing (Rees 2002). Gender mainstreaming now needs to be expanded to include gender analysis in basic and applied research. Mainstreaming gender analysis into research creates 'Gendered Innovations'.

Creating New Knowledge and Design

Gendered innovations use gender as a resource to create new knowledge. It is crucially important to identify gender bias and understand how it operates in science, medicine, and engineering. But analysis cannot stop there: focusing on bias is not a productive strategy. Gender experts are now shifting emphasis away from critique towards a positive research programme that employs gender analysis as a *resource* to achieve excellence in science, medicine, and engineering (Klinge 2008; Schiebinger 2008; Wajcman 2007; Schraudner and Lukoschat 2006; Faulkner 2001).

There is an urgent need for gender experts, natural scientists, and engineers to work together to develop internationally agreed upon methods of sex and gender analysis that can serve as a basis for understanding how gender functions in research. Gender analysis must become an integral part of identifying priorities and designing research. As the World Health Organisation states, 'It is not enough simply to 'add in' a gender component late in a given project's development. Research must consider gender from the beginning' (WHO). Sex and gender analysis act as yet further controls—one set among many—providing critical rigour in science, medicine, and engineering research, policy, and practice.

The European Commission DG Research & Innovation currently seeks to train researchers in how to integrate sex and gender analysis into research (Yellow Window 2009). In 2006, Fraunhofer Gesellschaft, the German industrial applied research engine, was funded by the German Ministry for Education and Research to prepare a checklist to help technology designers and engineers identify key gender components of their projects (Schraudner 2010; Biihrer and Schraudner 2006; Schraudner and Lukoschat 2006). The Austrian 'FEMtech' and Danish 'Female Interaction' projects, funded by national governments, also operationalize sex and gender analysis for designers (FEMtech; Schroder 2010).

These projects demonstrate that more systematic approaches are required. In 2009, the Clayman Institute for Gender Research at Stanford University initiated the Gendered Innovations in Science, Medicine, and Engineering Project (Gendered Innovations). This project has been expanded internationally through a collaboration with the European Commission in 2011 entitled Innovation through Gender. Systematic methods of sex and gender analysis are being produced in a series of expert meetings in 2011 and 2012. These meetings bring together gender experts, basic scientists, engineers, public health and medical experts, policy makers, and technology designers.

The purpose is to develop practical methods of sex and gender analysis for researchers. Emerging methods of sex and gender analysis are listed in Figure 7.1.

The Gendered Innovation project demonstrates methods through case studies. Each section below presents a case study highlighting a problem, a method of sex or gender analysis important to overcoming the problem, and a solution, or gendered innovation.

Methods of Sex and Gender Analysis serve to enhance scientific and technological excellence. The methods listed here represent a *minimum* set of issues that researchers should consider. As with any set of methods, researchers will fine-tune methods to their specific enquiry. The value of these methods depends, as with any intellectual endeavour, on the talent and creativity of the research team.

1. **Formulating research questions/ Envisioning design**
2. **Analysing research priorities and social outcomes**
3. **Analysing sex**
4. **Analysing gender**
5. **Analysing covariates (age, socioeconomic status, region, etc.)**
6. **Sampling**
7. **Analysing reference models**
8. **Analysing knowledge created through social divisions of labour (physical and cognitive)**
9. **Participatory research**
10. **Rethinking language and visual representation**
11. **Rethinking stereotypes**
12. **Analysing academic disciplines**
13. **Redefining key concepts**
14. **Rethinking theory**
15. **Rethinking decision-making processes**

Figure 7.1 Emerging Methods of Sex and Gender Analysis

Example 1. Technology Design: Pregnant Crash Test Dummies

a. The problem: Conventional seatbelts do not fit pregnant women properly, and in the US, 82% of foetal deaths with known causes result from motor vehicle collisions (Weiss *et al.* 2001, 1863). Because millions of pregnant women drive every year, the use of seatbelts in pregnancy is a major safety concern (Ventura *et al.* 2001, 1). When a lap belt is placed over (rather than under) the pregnant belly, force transmitted through the uterus increases three- to fourfold (Pearlman and Viano 1996, 977). Seatbelts were first installed in automobiles in the 1950s, and commonly used since the late 1980s. However, it was not until 1996 that researchers invented pregnant crash test dummies to test crash safety in foetuses. Even today, governments for the most part do not mandate pregnant crash test dummies in automobile safety testing.

*b. Methods of analysis—# 7 Reference models (*Figure 7.1*):* In much engineering design, men are taken as the norm; women are analysed as an afterthought and often studied from the perspective of how they deviate from the norm. This means that women may be left out of the 'discovery' phase—as a result, many devices are adapted to women retrospectively, if at all. In this case, the three-point seatbelt was designed with no attention to pregnancy.

Many years later, a supplementary strap was developed (to hold conventional lap belts in place) in efforts to fix the original design. A better solution might be a completely new basic design, a four-point seatbelt, perhaps, that works without a lap belt (Duma *et al.* 2006, 1). From the start, devices should be designed for a broad population to enhance safety and ensure a broad user base.

c. Gendered innovation: Solutions to safety testing are emerging from Sweden. Volvo's 'Linda', designed in 2002 by mechanical engineer Laura Thackray, is the world's first computer simulated pregnant crash-test dummy. 'Linda' generates data modelling the effects of high-speed impact on a woman and foetus. Automobile manufacturers, however, have yet to implement an alternative to the three-point seat belt.

d. Further comments: Using methods of sex and gender analysis from the beginning would have helped engineers avoid leaving out pregnant women. Sampling (method #6, Figure 1) encourages designers to study user populations and to include both men and women in design development. These men and women should represent people from different regions, social classes, ages, reproductive status, etc. Analysing sex (method #3, Figure 7.1) encourages designers to look at sex-specific characteristics of men and women. Pregnancy should not be overlooked.

Example 2. Civil Engineering to Secure Water Supplies

a. The problem: Millions of people worldwide lack reliable, efficient access to water.

b. Methods of analysis: Analysing social divisions of labour (method #8, Figure 7.1) helps researchers understand who in a community holds the knowledge required for a particular project. Women, as traditional water fetchers, often have specialized knowledge concerning water sources. Participatory research (method #9, Figure 7.1) calls for women with specialized knowledge to be engaged in development projects from the start. Increased diversity in research teams helps to enhance results.

c. Gendered innovation: Social divisions of labour in much of Africa make water procurement women's work. Consequently, women have detailed knowledge of soils and their water yield. A study of water projects in 13 nations revealed that 'equal representation and participation by women contributes to the success of community-managed water services' (Postma *et al.* 2003, 13). Women's participation correlates strongly with project sustainability as well (Gross *et al.* 2001).

Example 3. Medical Research: Cardiovascular Disease

a. The problem: Cardiovascular disease is the leading cause of death for women in the United States, Europe, and in many developed countries (American Heart Association 2011). Despite this, cardiovascular disease has long been defined as a male disease, and clinical standards and treatments have been developed for men.

b. Methods of analysis: Researchers must analyse disease reference models (method #7, Figure 7.1). In the case of cardiovascular disease, myocardial infarction or 'heart attack' symptoms were modelled in men and the results generalized to the entire population. Symptoms, however, can differ between men and women. Men typically experience pain in the chest and left arm. Women often experience chest pain along with a series of less recognized symptoms, such as nausea and vomiting, pain in the right arm and back, fatigue, cold sweat, and dizziness. Because women's symptoms do not match 'standard' (male) symptoms of myocardial infarction, women are often misdiagnosed and improperly treated (Mosca *et al.* 1997, 2468).

c. Gendered innovation: Including women as research subjects (analysing sex, method #3, Figure 7.1) has led to the discovery of important sex differences in myocardial infarction symptoms, diagnostic testing, and preventative therapies. Further, analysing covariates (method #5, Figure 7.1) has led to the discovery that risk differs significantly by ethnicity and socioeconomic class. In the United States, African-American women have 28% higher cardiovascular disease mortality compared to the overall female population (American Heart Association 2011).

Example 4. Osteoporosis: Sex and Gender Analysis Also Benefits Men

a. The problem: It is important to understand that gender analysis relates to men as well as women. Osteoporosis is a disease traditionally seen as affecting postmenopausal women, and men have historically been excluded from osteoporosis research in much the same way as women have been excluded from cardiovascular disease research. Current diagnostic criteria for osteoporosis are based on the relationship between bone mineral density (BMD) and fracture risk in postmenopausal white women, resulting in under-diagnosis of osteoporosis in men (Faulkner and Orwoll 2002, 87). Yet men suffer from a third of all osteoporotic-hip fractures, and have higher average mortality than women with similar injuries (Sweet *et al.* 2009, 193).

b. Methods of analysis: Examining sex in diagnostic reference models (method #7, Figure 7.1) in osteoporosis research has broken the gender paradigm and turned attention to understanding the disease in men.

c. Gendered innovation: Diagnostic criteria are beginning to include men (Cummings *et al.* 2006, 1550).

Example 5. Stem Cells: Analysing Sex

a. The problem: Stem cell research has failed to evaluate differences between XX and XY stem cells (Wizemann *et al.* 2001). By failing to consider sex, researchers may be overlooking important aspects of how XX and XY cells work differently in human bodies.

b. Method of analysis: Analysing sex (method #3, Figure 7.1)—both reporting sex and designing research to analyse data by sex—can lead to important breakthroughs. Researchers need to: 1) identify the sex of cell lines; 2) prospectively design experiments for meaningful analysis of sex differences of results (not all sex differences will be significant); 3) record and format data in ways that allow for systematic review or meta-analysis.

c. Gendered innovation: Sex analysis is beginning to reveal that the sex of stem cells matters: clinical outcomes of stem cell transplantation can differ depending on the sex of donor cells used, the sex of the host, the type of stem cells transplanted, and the disease being treated (Csete 2008, 232).

CONCLUSION AND RECOMMENDATIONS

Employing gender analysis to stimulate innovation in science, medicine, and engineering involves interdisciplinary coordination throughout the research process—from making policy about what fields of research to fund, to refining methods of sex and gender analysis in basic and applied research, to the process of hiring and promoting faculty, to the reviewing of manuscripts for publication. Realizing the full potential of gendered innovations in the next decade will also require international cooperation to match the global reach of science and technology, as recognized in the European Commission's genSET *Consensus Report* and the United Nations resolutions on Gender, Science and Technology (genSET 2010, 6; UN Women 2011).

Once methods of sex and gender analysis are in place, there are a few further steps. These involve both researchers and research institutions:

1. **Train current researchers** and evaluators in gender methodology. The genSET project offers a good model for how to engage researchers as active participants in gendered innovations (genSET 2010).
2. **Hold senior management accountable** for developing evaluation standards that take into account proper implementation of sex and gender analysis in research. There are several practical ways

to encourage researchers to develop proficiency in sex and gender analysis:

a. **Granting agencies** can require that all applicants specify whether, and in what sense, sex and gender are relevant in the objectives and the methodology of their project. Research projects that fulfil this criterion might achieve a higher score for funding. Researchers might also achieve this score by demonstrating that sex or gender is not relevant to a particular project. It is important, however, that the issue be addressed.
b. **Hiring and promotion committees** can evaluate researchers and educators on their success in implementing gender analysis. Knowledge and use of methods of sex and gender analysis can be one factor taken into consideration in hiring and promotion decisions.
c. **Editors of peer-reviewed journals** can require sophisticated use of sex and gender methodology when selecting papers for publication. A number of journals do this: the *Journal of the American College of Cardiology,* the *Canadian Medical Association Journal,* and *Circulation*[3], the American Heart Association journal. *Nature* is considering adopting this policy (Nature Editorial 2010, 665). Journals should also enforce consistent use of key words such as 'sex' and 'gender' to facilitate meta-analysis.

3. **Train the next generation** in methods of sex and gender analysis. Sex and gender analysis should be taught throughout the curriculum, including basic science, medicine, and engineering courses. It is important that research institutions support programmes in gender research where experts develop new knowledge concerning gender, science, medicine, and technology. Yet at the same time, gender analysis must also be taught to future scientists and engineers. In this way, students in technical fields learn methods of sex and gender analysis continuously throughout their studies. Textbooks should be revised to integrate sex and gender results and methods.

Innovation has been placed at the heart of the Europe 2020 strategy (European Commission 2010a). Innovation is seen as a way to address major social problems as well as stimulate economic development. Gendered innovations in science, medicine, and engineering employ sex and gender analysis as a resource to stimulate creativity, and by doing so enhance the lives of both men and women. As this paper suggests, gender analysis sparks creativity by offering new perspectives, posing new questions, and opening new areas to research. Can we afford to ignore such opportunities?

NOTES

1. Parts of this paper were included in a keynote address for the Oesterreichische Forschungsgemeinschaft by Londa Schiebinger and have been published in their proceedings: *Wissenschaft und Gender*, ed. Gottfried Magerl, Reinhard Neck, and Christiane Spiel. Vienna: Boehlau, 2011.
2. 'The Research Council views it as essential that gender perspectives are given adequate consideration in research projects where this is relevant. Good research must take into account biological and social differences between women and men, and the gender dimension should be one of the main pillars of the development of new knowledge. In research projects this dimension may be manifested through the research questions addressed, the theoretical approaches chosen, the methodology applied, and in the efforts to assess whether the research results will have different implications for women and men'.
3. *Circulation* (Journal of the American Heart Association) Instructions for Authors state: 'Please provide sex-specific and/or racial/ethnic-specific data, when appropriate, in describing outcomes of epidemiologic analyses or clinical trials; or specifically state that no sex-based or racial/ethnic-based differences were present'. http://content.onlinejacc.org/misc/ifora.dtl. (10/2/11)

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CHAPTER 8

The Gender Gap in Patents

Sue Rosser

Software engineer Joan Jetma works at a very large global information technology company that prides itself on innovation and rewards its employees for patenting innovative discoveries. Joan had observed that very few women in the company where she worked obtained patents. When she did some research to determine whether her observations were correct, she learned that data are scarce on the number of women who patent both inside and outside her company. She discovered that about 10 percent of the women obtained patents at her company. When her own patent came up for review, she realized that all of the reviewers were men.

> Patents weigh heavily for some promotions and career advancement in the company, which considers itself a leader in innovation. Not only do individuals who patent receive financial rewards, but patenting can be a make or break difference for certain promotions, For example, it's impossible to become a Fellow or Distinguished Engineer without having patented at the company where I work.

My own career and research had long made me aware of the importance of mentoring, institutional barriers, and leadership in the careers of women scientists and engineers, but it was not until recently that a young male faculty member in a different department made me aware of a new issue, critical for women in science, of which I had previously been ignorant. When he first brought the issue of gender and patents to my attention, my reactions ranged from how boring to who cares? Fortunately the new faculty member was persistent, bringing up the issue again at a reception, when he bumped into me in the hall, and finally when he made an appointment to discuss it with me.

On some level, I wondered if my resistance came from the realization that a gender gap in patents would mean that women had been left out of the leading edge of science yet again. Was this yet another new face of this old issue? After more than 30 years of studying issues of women, science, and technology, and working actively on the national and local levels to implement programs (Rosser and Lane 2002b) to increase the numbers of women scientists and engineers, I couldn't bear to recognize the old pattern of women achieving parity in one area, just as the men lead the shift to a new, different arena.

As a dean, of course, I felt obligated to take the research interests of my faculty member seriously. The more I investigated the gender gap in patents, the more I began to see that it represents a very critical issue for women in science today. Although I didn't know very much about patents, as a dean at a doctoral research extensive technological institution, I was keenly aware of the increasing significance of technology transfer and commercialization of science. In the United States, Japan, and many European countries, most research universities are placing increasing emphasis upon innovation and applied research. This results in blurring of boundaries between academia and industry. Technology transfer and licensing offices and increased percentages of total research funding coming from industry, as well as conflict of interest policies that spell out ethical ways for faculty to commercialize the products that result from their federally funded research conducted at the university, mark the evidence of the commercialization of science and this blurring. Even the most distant faculty colleagues in humanities and fine arts become aware of the trend when they read about the unanimous 2006 decision of Texas A&M University to include inventions in tenure and promotion decisions (Zaragoza 2008); when they serve on a university tenure and promotion committee where a lengthy discussion emerges over how much weight patents should be given compared to peer-reviewed publications in a promotion decision; or when they serve on the committee to determine how to modify existing policies on sabbaticals and research leaves for faculty who wish to take one or more years away from the classroom for a "start-up" company.

Most faculty also recognize the drivers for this trend toward applied research and increasingly closer relationships between the corporate world and academia. The exciting work emerging from new interdisciplinary fields such as biotechnology, nanotechnology, and information technology have spawned many of these stimulating intellectual relationships. Those very names suggest the application (technology) to basic science discoveries in molecular biology, materials, and computer science. These new fields have experienced remarkable growth. For example, patents in information technologies have shown a fivefold increase from the early eighties (1980–1985) to the early twenty-first century (2000–2005) (Ashcraft and Breitzman 2007).

De-funding of higher education, particularly by state legislatures, has forced public institutions into closer relationships with corporations. Relatively flat funding from the federal government for research and education in physical sciences and engineering until the President's proposed 2009 budget, combined with flattening of the National Institutes of Health (NIH) budget after its doubling from 1998–2003 to support health and bioscience, provided further impetus for the university-industry relationship. The economic crash beginning in 2008 has led to budget cuts for universities that will ultimately impact research productivity; the results of the Stimulus Package remain to be seen.

Spurred by several reports produced by the National Science Board (NSB 2004), the National Academy of Sciences (2007), and the Council on Competitiveness (2005), the U.S. Congress has begun to recognize science, technology, and innovation as crucial keys for insuring the competitive edge of the United States in the global economy. The tightening on visa restrictions in the wake of September 11 underlined the dependence of the U.S. science and technological enterprise on students from other countries and professionals who are immigrants on H-1B visas. Globalization and the flattening of the world described by Thomas Friedman uncovered the possibilities for loss of U.S. innovative competitiveness. In August 2007, the U.S. Congress held hearings on future directions for science and technology in general and on ways to improve the 1980 Bayh-Dole Act in particular, to rebalance incentives for patents, transfer, and licensing between corporations and universities. The focus on patents reflects their significance as a measure of innovation. In September, 2011 a U.S. patent reform was signed, changing the law from first to invent to first to file or publish.

Much of the current funding available from federal agencies, along with corporate funding, is now allocated to fund applied research, commercialization, and technology transfer. The funding as well as the bonuses, stock options, and hefty salaries paid to scientists who serve on advisory boards to start-up companies means that a gender gap in patents signals the old dilemma of women again being left behind, since patents are a primary indicator of technology transfer.

WOMEN IN SCIENCE AND TECHNOLOGY

Just as globalization, constraints brought on by September 11, and new interdisciplinary fields in science and technology have increased focus on commercialization of science and innovation in the United States, they have also brought renewed attention back to issues of women in science and technology. Reports released from the National Academy of Sciences (2007) such as *Rising Above the Gathering Storm,* as well as *Innovate America* (Council on Competitiveness 2005), and *Science and Engineering Indicators* (National Science Board 2004), spell out the anticipated workforce shortage. They also underline the extent to which the U.S. science and engineering workforce has depended upon students from other countries to provide well-qualified and motivated graduate students and immigrant scientists and engineers to keep both U.S. industrial and academic science staffed. September 11, 2001 not only caused entry problems via H-1B and student visas, but it also changed the desire of many scientists, engineers, and students to come to the United States. The projected dearth of scientists and engineers resulting from the decrease in immigrant scientists has caused the focus to shift to underutilized sources within the U.S. population to fill the gap. Women represent the largest underutilized source. (See Chapter 3 for the statistics on women in STEM.)

Juxtaposing the increasing emphasis of global science and technology on innovation with the data on gender participation in the science and technology workforce reveals an additional issue of potential consequence both for women scientists and engineers as well as for the competitiveness of the United States. The percentage of women granted patents ranks significantly lower than that of their male peers. Not only is the percentage of women obtaining patents lower than men, but it also ranks very low relative to the percentage of women in the STEM disciplines.

Curiosity drove me to explore the gender gap data in different disciplines, sectors, and countries. The evidence proved overwhelming. In all countries, in every discipline, including those such as biology, in which women had begun to approach parity, the gender gap remained substantial, whether in government, academic, or private sector.

MEASURES OF PRODUCTIVITY: PATENTS AND PUBLICATIONS OBTAINED BY U.S. WOMEN

A patent is a set of exclusive rights granted by a national government to an inventor for a time-limited period in exchange for public disclosure of the invention. Usually a patent application includes one or more claims defining the invention, which must be new, inventive, useful, or industrially applicable. Since national laws and international agreements govern patents, the procedures for granting them, as well as the requirements and extent of exclusive rights, vary quite a bit depending upon where the patent was granted.

Quantifying gender and patents becomes a difficult exercise. Many patents bear the names of several individuals, often including lawyers and other individuals who work for the company but who have little to do with the invention itself. Some counts include all patents with at least one woman inventor. For example, a 2007 study from the National Center for Women and Information Technology reported that from 1980 to 2005, approximately 9% of U.S.-invented IT patents had at least one female inventor. Others use fractional counts. When the fraction of the patent that can be counted as female is calculated, the overall percentage of female U.S.-invented IT patents drops to 4.7%, although the fractional percentage has increased from 1.7% in 1980 to 6.1% in 2005 (Ashcraft and Breitzman 2007). This positive increase in percentage of patents by women occurred during a period when the percentage of women employed in IT decreased slightly, from 32% in 1983 to 27% in 2005 (Ashcraft and Breitzman 2007). Nonetheless, these data underline that 93.9% of U.S. origin patents come from men, who constitute approximately 70% of the U.S. IT workforce. The percentage of U.S. origin patents obtained by women in IT ranks well below their percentage in the IT workforce.

Although women are closer to parity in numbers and percentages in the life sciences, a similar gender gap pattern found in other fields with regard to patenting appears to occur in the life sciences (Ding, Murray, and Stuart 2006). A study of more than 1,000 recipients of NIH training grants in cellular and molecular biology revealed that 30% of men compared to 14% of women recipients had patented (Bunker Whittington and Smith-Doerr 2005). In contrast, this same study revealed that women's patents are more frequently cited than those of the men, suggesting a similar pattern to that found in earlier studies of publication rates in which men published more than women but that women's publications were cited more frequently (Long 1993). Citation, in both patents and publications, reflects the significance or importance of the work and how much other scientists or engineers use it as a basis for reference for their work.

A study restricted to a sample of 4,227 life science faculty found that 5.65% of the women and 13.0% of the men held at least one patent, despite no significant differences in publication patterns (Thursby and Thursby 2005). The lower percentage of women obtaining patents appears to hold across sectors of government, academia, and industry (Stephan and El-Ganainy 2007; U.S. Patent and Trademark Office 2003) with the exception of science-based network firms in the biotechnology industry (Whittington and Smith-Doerr 2008), where women are equally as likely as men to become involved in patenting, but still do not patent as frequently as men.

Women also tend to have lower publication rates than men, but the gender disparities in publication rates are not as significant as those for patents. For the United States, Yu Xie and Kimberlee Shauman (2003) document that women publish at about 70–80% of the rate of men, based on 1988 and 1993 databases. In her study of tenured or tenure-track faculty in doctoral granting departments in computer science, chemistry, electrical engineering, microbiology, and physics in 1993–1994, Mary Frank Fox (2005) found that men are twice as likely as women to publish 20 or more papers, while women are almost twice as likely as men to publish zero or one paper. Fiona Murray and Leslie Graham (2007) found that men at "Big School" had higher total publication counts (82 vs. 55) and higher publication counts per year

(3.7 vs. 2.6) than women, although these were not statistically significant; however, the citation counts per paper were very similar (42 for men vs. 41 for women). The significant difference between men and women was that men published 16% of their publications jointly with industry, while women published only 6% jointly with industry (Murray and Graham 2007, table 1).

An additional issue, not exactly paralleled in citation counts for papers, arises surrounding quality or impact of patents. Patents are obtained both to protect new inventions or ideas, as well as in business to prevent others from using or developing linked components critical to the basic operation of the invention. It is the latter type of patent, particularly common in computing, that many claim are "junk patents" that are "putting too many patents of dubious merit in the hands of people who can use them to drag companies and other inventors to court" (Tessler 2008, 1). One possible way to read the higher citation count for women's patents is to assume that women hold fewer patents of "dubious merit" compared to men.

INTERNATIONAL COMPARISONS OF PATENTS OBTAINED BY WOMEN

Unfortunately, the gender gap also appears to hold internationally. Since patent offices do not record the gender of inventors for each patent (Ashcraft and Breitzman 2007), relying on names makes determination of gender difficult in some instances, particularly for gender-ambiguous names (Chris) or for names commonly applied to women in some countries and men in others (Jean in the United States compared to France). Using complicated and labor-intensive techniques, researchers have evolved methodologies to match gender with patents for large databases internationally. This reliance on names constitutes a further complication to studying the gender gap in patents. Catherine Ashcraft and Anthony Breitzman (2007) compared female IT patenting rates in the United States and Japan. Fulvio Naldi and Ilaria Prenti (2002) used large databases to study gender differences in patenting and publications in the United Kingdom, France, Germany, Italy, Spain, and Sweden in biology, biomedical research, chemistry, clinical medicine, earth and space, engineering, mathematics, and physics. Frietsch et al. (2007) studied gender differences in patenting and publications in those same fields and in those same six countries plus eight others: Australia, Austria, Belgium, Denmark, Ireland, New Zealand, Switzerland, and the United States.

Using the Scopus database that covers more than 15,000 peer-reviewed journals in the life sciences, health sciences, physical sciences, and social sciences, Rainer Frietsch and colleagues (2007) found that the share of female authors varied by country between 21.5% (Switzerland) through 28.3% (United States) to 38.6% (Italy). He also found considerable variation by field, with biology (33.9%), biomedicine (32.2%), and medicine (28.3%) having the largest share of female authors, while engineering (20.4%), physics (18.1%), and mathematics (16.3%) had the least. Chemistry (25.3%) and geosciences (21.8%) were intermediate. His data of share of female authors by discipline and country suggest that women publish somewhat less than men in each field but that women's publication rates are significantly higher than their patenting rates in all countries and all fields.

All these studies document that in all of these countries in all of the different areas, the percentage of women obtaining patents is significantly lower than that of their male counterparts. Considerable variation exists among the technological fields, with pharmaceutical (24.1%) and basic chemicals (12.5%) tending to have higher percentages of patents obtained by women, and machine-tools (2.3%) and energy machinery (1.9%) having lower percentages in 2001 (Frietsch et al. 2007). Within the IT industry, some variation occurred among subcategories, with women obtaining about 8% (fractional count) of the computer software patents in the United States and about 6% (fractional count) of patents in other fields such as hardware, semiconductors, communications, and peripherals. Relatively the same subcategory distributions held for Japanese women, but at lower percentages overall, since Japanese women obtained about 3.0–3.6% (fractional count) of patents overall but 5.6% (fractional count) of the software patents.

As suggested by the comparison of U.S. and Japanese women in IT, considerable differences in the percentage of women obtaining patents occur among countries. The study of patenting in 14 countries (Frietsch et al. 2007) documented that in general the percentage of women's patenting has increased during the past decade in all countries. However, substantial variations exist among countries, even within Europe. Australia (13.7%), Spain (17.5%), and New Zealand (14.0%) rank highest; Switzerland (7.4%), Germany (5.9%), and Austria (4.5%) rank lowest. The United States (11.1%), Sweden (9.3%), and Denmark (11.4%) rank about midway in percentage of women obtaining patents (Frietsch et al. 2007). In all countries, the percentage of women obtaining patents is less than the percentage of women in the STEM workforce.

Issues surrounding quantification, quality, and association of some names with a particular gender might raise doubts if the gender gap in patents were small or not evident in all sectors, disciplines, or countries. But the gap is substantial. In short, in all countries across all sectors and in all fields, the percentage of women obtaining patents is not only less than their male counterparts but it is less than the percentage of women in STEM in the field in the country. This raises the following questions: what are the impacts and nature of the gender gap, and what can be applied from women's studies and gender studies to close this gender gap in patenting?

Both in the United States and internationally, the focus for scientific research has shifted from basic to applied research and innovation, for which one of the primary indicators is patents granted. If women scientists and engineers are not obtaining patents at rates comparable to their participation in the STEM workforce and at significantly lower rates than their male peers, then women are not participating in the new areas and directions for science and technology. This hurts women scientists and engineers who are left out of the leading-edge work in innovation. Women are then not seen as leaders in their field, which hurts women financially and in their professional advancement. Commercialization of science can be extremely lucrative, if the patent results in a product that is developed, brought to market, and is successful. Since patents "count" as a marker of success, similar to publications, and may even be required for some bonuses and "fellow" status in some industries, women's small percentages of patents also inhibit their professional advancement. Although men dominate patenting in all fields, some relative gender differences in fields of patents exist.

WHAT IS THE IMPACT OF GENDER INEQUITY IN PATENTS?

Having a relatively small number of women obtaining patents hurts scientific innovation, technology, and competitiveness overall. As feminist critiques (Keller 1983; 1985) of science have revealed, science is gendered in ways that bind objectivity with masculinity so that a latent, diffuse assumption that scientists are working toward the common good permeates approaches and results of science, when in fact it may be working for the good of only some races, classes, and one gender. When women entered science in larger numbers, they revealed androcentric approaches that included biased questions, approaches, and theories and conclusions drawn from data. Similarly, the predominance of men in patenting may mean that innovations useful for a broader population may not be developed.

Having large numbers of male engineers and creators of technologies often results in technologies that are useful from a male perspective. In addition to the military origins for the development and funding of much technology (Barnaby 1981; Norman 1979), which makes its civilian application less useful for women's lives (Cockburn 1983), technology for the home that is designed by men frequently focuses on issues that are less important to women users. For example, Anne-Jorunn Berg's (1999) analysis of "smart houses" reveals that such houses do not include new technologies; instead they focus on "integration, centralized control and regulation of all functions in the home" (306). "Housework is no part of what this house will 'do' for you" (307). Knowledge of housework appears to be overlooked by the designers of smart houses. As Ruth Schwartz Cowan's (1983) work suggests, the improved household technologies developed in the first half of the twentieth century actually increased the amount of time housewives spent on housework and reduced their role from general manager of servants, maiden aunts, grandmothers, children, and others, to an individual who worked alone doing manual labor aided by household appliances.

Although men do dominate patenting in all fields, some relative gender differences in fields of patents exist. Since ideas for patents often arise out of personal experience, it is not surprising that studies (Macdonald 1992) of the patents obtained by women and of women inventors document that women invent more technologies related to reproduction or children. Women also have invented many technologies for the home (a patented house that cleans itself, using 68 separate devices), and for caretaking, particularly of children (disposable diapers and the pull-down-from-the-wall baby-changing stations found in public restrooms). If more women were involved in commercialization, imagine the new, useful products that might be developed to benefit society.

REASONS FOR THE GENDER GAP IN INDUSTRY

Exclusion or self-exclusion of women from commercialization of science and patenting hurts both women and science, while also shortchanging society. Patenting has been integral to technical and scientific firms for more than two centuries and remains central and significant for the culture of most science and technology corporations. As noted previously, not only do those who patent reap significant financial rewards and recognition, but a track record in obtaining patents is required for individuals to attain certain positions in their fields. As suggested in the previous chapter, some scientists and engineers move back and forth among the private, academic, and government sectors. Since the gender gap in numbers of patents obtained by women remains in industry, where the rewards, incentives, and motivations for patenting are more positive and clear, I thought that attempting to understand some of the reasons behind the gap in industry might help begin to understand the gap in academia, where the impact of patents on the academic career path may be mixed or not well understood.

Interview Data and Methods

I conducted interviews with ten people, two men and eight women, who served as software engineers, vice presidents, chief executive officers, or presidents of technology companies in the metro New York City area and in California's Silicon Valley. Although two individuals had worked at the same company in different positions during their entire careers, most had worked at a variety of companies, both large and established and small and startup. Interviewees were obtained using the snowball method; at the close of each interview, I asked who else in another company in the area I should ask these same questions to help me better understand the gender gap in patenting. All names and other identifiers of interviewees have been changed.

Each interviewee was asked the following five questions:

1. What is the percentage of women, compared to men, obtaining patents at the company(ies) with which you have been associated? How does that compare with the overall percentage of women in the company?
2. What role do patents play in advancing one's career in the company? Are patents becoming more or less important than they were 10 years ago?
3. Why don't women patent at the same rates as men? What are the barriers?
4. How can we increase opportunities for women to patent? What actions is your company taking to facilitate this?
5. What (else) should I have asked about women and patents?

The quotations that follow from three interviews are representative of the broader set of data collected.

I conducted an interview with technology sector CEO Sharlane Levitan.* Sharlane finds from her experience in both large and small technology companies that women have different motivations and interests that may make them less likely to patent.

CEO Sharlane Levitan

Sharlane Levitan has worked in very large technology companies in a variety of roles, mostly on the marketing and development sides, as well as serving as CEO of two small technology companies. She believes that one reason women patent at lower rates than their workforce numbers in the IT industry is that most women move to the marketing, development, and human resource sides of the company. Although they may start in engineering or software development, many women move into the operationally oriented roles, which are less likely to be areas from which patents emanate.

> In general, women are less interested in technology and more interested in socially oriented areas. I believe that the way to motivate women and retain them in technology is to emphasize context, creativity, and the arts side of technology for which women may be more hard-wired. Simultaneously, I believe that most women do take a risk-averse approach to their career that inhibits their ability to think boldly and persistently about one big idea that might be patentable. To overcome these differences in motivation and risk aversion, companies should make mentoring others in the process of patenting part of performance plans and develop R&D training programs to teach women about the process of patenting. That would help to change the climate and motivation for women to patent.

Levitan's notions of women's risk aversion also seemed to stem from the fact that women are more interested in and occupied with children and family, which might lead them to develop more patentable ideas in these arenas than in IT. Indeed, her contention receives some support from evidence derived from the studies of inventions by women and surveys of patents obtained by women (Macdonald 1992) which suggest that many women develop technologies related to reproduction (e.g., Nystatin to prevent vaginal yeast infections), secondary sex characteristics (backless bra), or babies/children (folding crib).

When I pressed her a bit, Sharlane admitted that it might not be the biological differences between men and women, but the societal views of gender based on biological differences as suggested by existentialist Simone de Beauvoir (1949) that resulted in this gender gap in patenting in IT.

When I interviewed women in industry about the gender gap in patenting, they immediately knew what I was talking about and told me what they believed to be the reasons the gap persists. In contrast, when I spoke with men in industry, most of the interview was spent challenging the data that the gap existed at all. After they became convinced that the gap might be real, they stated that it might hold for other companies, but they were pretty sure it was not true for theirs, although they had never thought about it or looked into it, as the my interview with Rick Foot* reveals.

President Rick Foot

Rick Foot currently serves as president and founder of a very successful IT innovation company. He has started up other companies and headed several research and development operations. Friendly and generous with his time for the interview, he began by explaining the patenting process.

He told me that he didn't think there was a gender gap in patenting in the industry but that it must result from the persistently low numbers of women in the industry. When I explained the NCWIT study and the data showing that women patented at much lower rates than their participation in the IT workforce, he challenged the data with other questions about sector, publication rates, incentives, and age. When he finally accepted that the data for the gender gap might be solid, he said, "I'm pretty sure that the women in R&D in my company patent at the same rate as their many male counterparts." He did admit, though, that he had never thought about gender or checked the data for his company, which he became intrigued to examine. Rick Foot was quite convinced that his view—that there could not be a gender gap in patenting or if a gap did exist, it was proportional to the low number of women in IT—was absolutely true.

I conducted the following interview with Sal Calfit*, a software engineer who works at one of the largest global information technology companies in the world. Concerned about the dearth of women obtaining patents in the company, she formed a community to support them and help them learn the process.

Software Engineer Sal Calfit

Sal had observed that very few women in the company where she worked obtained patents. That stimulated her to start the support community for women. She sent an email to about 20 women in the company; she immediately received responses from all around the globe. In two years, the community has grown to 600 women who represent all sectors and all countries where the company is located.

> I believe that a variety of factors account for the low numbers of patents obtained by women. Women look critically at themselves and their ideas, wondering whether they are meritorious. They need someone both to encourage and to guide them through the process. Women also tend to be the workhorses on the team; they are more focused on getting the job done than the external rewards.
>
> I also believe that women have less access to networks, which is why the network

> I created provides a lifeline for these women. The women seem to love the community atmosphere; they appear to crave the brainstorming, support, and nurturing atmosphere. Communities of the company are now springing up in China and India with large memberships of women.

In setting up the online support community for women in her company, Sal Calfit tries to provide access and level the playing field for women in other countries. The interest of women in India and China working for the corporation in the online communities to support patenting reflects the varying complex aspects of the inter-relationships among developed and developing countries in general and between the particular cultures of the colonized and colonizing country.

The particular forms and ways that these shape and play out vary, depending upon the history, culture, geography, and duration of colonization for both the colonized and colonizing countries. For example, the IT industry uses subcontracted female labor in developing countries, particularly for software development. Practically, the ties developed between colony and colonizer, as well as the language of the colonizer learned by the colonized during the period of colonization, means that former relationships continue in the neocolonial modern world (Rosser 2005, 15–16).

Using feminist theoretical frameworks to contextualize responses of interviewees provides some further insights into the gender gap in patenting in industry. Some of the studies about the gender gap in patenting for academic women also point to issues of access and discrimination. For example, Murray and Graham (2007) conducted semi-structured interviews of 56 life science faculty about their experiences with commercial science at “Big School.” Only 23% of women faculty had patented, while 74% of men faculty hold at least one patent. Women faculty reported fewer opportunities and referrals from collegial networks to participate in the commercial marketplace by being asked to consult, serve on science advisory boards, and interact with industry, resulting in women becoming less socialized to commercial science. This led to women having fewer chances, relative to their male colleagues, to resolve ambiguities that many life scientists hold about commercial science.

Murray and Graham (2007) then appear to move beyond issues of access to explore what might be described as almost a psychoanalytic approach, reminiscent of the work of Evelyn Fox Keller. They state, “Partly because of the dearth of women, the practices of commercial science, including those surrounding money and competition, became constructed as male” (Murray and Graham 2007, 682). Murray and Graham found that male constructions of “these intersections were reinforced across generations by homophily in mentoring and networks, work-family issues, and broader societal stereotypes towards women in commercial roles” (Murray and Graham 2007). Although the effects were more severe on senior women, in the “entire population of junior faculty, 44% of men have been granted patents compared to only 11% of women.” Although not stated explicitly, the presence of the continuing gap even among junior women implies that the liberal feminist approach of eliminating barriers will not be sufficient, as long as organizational and societal stereotypes remain unchallenged.

Paula Stephan and Asmaa El-Ganainy (2007) suggest that one aspect of the organizational context argument—that more men than women are employed at higher ranks at doctoral research extensive institutions where most patenting occurs—only partially accounts for the gender gap. Although they appear to recognize some of the structural and power issues surrounding why doctoral research extensive institutions with high prestige and better salaries are dominated by men, they do not really critique these organizational structures. The predominance of men employed at research I institutions, where wages are higher and hours are longer, results partly from a culture that is less family-friendly than that found at many less elite higher education institutions.

Stephan and El-Ganainy (2007) provide evidence from various studies to suggest the following explanations for the gap, in addition to employment at doctoral research extensive institutions:

- Women are more risk averse than men regarding financial decisions and may have less interest in money and a lower comfort level with financial transactions.
- Women dislike competition more than men, and commercial science is perceived as competitive.
- Women are less comfortable selling themselves and their science in the entrepreneurial manner needed for commercialization.
- Women are less likely to seek out opportunities to participate in commercial science.
- Women may choose areas for research that are less compatible with commercialization.
- Women have fewer characteristics such as high productivity and a "title" that venture capitalists like.
- Compared to men, women have more family constraints which they perceive as a tradeoff with their entrepreneurial activities,
- Women faculty may be less likely to be located in one of the three commercialization geographic "hot spots" in California, Massachusetts, or North Carolina.
- Women tend to have fewer peers involved in commercialization, partly because their collegial networks are likely to include more women than those of men. Women scientists may have fewer graduate students and postdocs than men and less diverse networks than men.

Some women, particularly those coming from a socialist feminist perspective, purposely avoid commercialization of their research which they view as "selling their science" to pander to capitalism. Current intellectual property rights agreements and laws provide opportunities for choices in technology development that further exacerbate class differences by transferring technologies developed using public moneys to the private realm through patents. The decisions regarding which products are developed falls under the influence of capitalist interests in profit margins. Such intellectual property rights function as a form of privatization (Mohanty 1997). They allow decisions about which products will be developed to occur in the private, rather than the public, realm. This results in capitalist interests in the bottom line, rather than public needs and interests, dictating which "products" are developed. New technologies in computer science and engineering are often developed using federal grants (paid for by taxes). In the patenting of intellectual property, rights (and profits) get transferred from the public who paid for the research with their tax dollars, to the private company, institution, or individual who controls the patent. Socialist feminists might view this as a transfer from the pockets of the working class, who pay the taxes to underwrite federal research, to the patent holders in the private sector who will reap massive profits, serving the interests of bourgeois capitalists.

Understanding that middle- and upper-class men create and design most new technology, along with serving as the sources of money for design and creation, explains much about whose needs are met by current technology and its design. The male norm is often used in technology design, resulting in the exclusion of women even as users of the technology. For example, military regulations often apply Military Standard 1472 of anthropometric data so that systems dimensions use the 95th and 5th percentile of male dimensions in designing weapons systems. This led to the cockpits of airplanes being designed to fit the dimensions of 90 percent of the male military recruits (Weber 1997). This worked relatively well as long as the military was entirely male. In the case of the joint Primary Aircraft Training System (JPATS), used by both the navy and air force to train the pilots, the application of the standard accommodated the 5th through 95th percentile (90 percent) of males, but only approximately the 65th through 95th percentile (30 percent) of females. The policy decision by Secretary of Defense Les Aspin (1993, 10) to increase the percentage of women pilots, uncovered the gender bias in the cockpit design. Designed to exclude only 10 percent of male recruits by its dimensions, the cockpit excluded 70 percent of women recruits, making it extremely difficult to meet the military's policy goal of increasing the number of women pilots. The officers initially reacted by assuming that the technology reflected the best or only design possible and that the goal for the percentage of women pilots would have to be lowered and/or the number of tall women recruits would have to be increased. This initial reaction, which represented the world viewpoint of men, changed over time. When political coalitions, the Tailhook scandal, and feminist groups reinforced the policy goal, a new cockpit design emerged which reduced the minimum sitting height from 34 to 32.8 inches, thereby increasing the percentage of eligible women (Weber 1997, 239).

Imagining women as designers, as well as users, of technology suggests that more technologies might meet the needs of women and be adapted for the spaces where women spend time. Socialist feminism would suggest that the allocation of resources for technology development should be determined by greatest benefit for the common good. For example, now that a larger percentage of the population is older, perhaps more technology to ease daily life for the elderly will be invented.

Venture capitalists may have a higher comfort level with men than women since most venture capitalists are men (Murray and Graham 2007). Gender discounting (viewing the accomplishments of women differently from those of men, when all else is equal) of women's work by industry may lead to fewer women being asked to participate in commercialization.

In brief, although more research on the reasons for the gender gap needs to be undertaken, it appears that a variety of factors concerning attitudes and socialization of women, balancing work and family, sexist attitudes of venture capitalists and industrial partners, as well as women's differing collegial networks and research focus, may serve as major contributors. Gender discounting of women's scientific work by industry, greater comfort level of venture capitalists with men than women, fewer opportunities for commercialization open to women, broader and more varied collegial networks available to men, and a boy's club atmosphere imply exclusion and being locked out, if not actual discrimination against women in commercialization of science. These suggest that the gender gap in patents is a feminist issue to which theories from gender and women's studies might usefully be applied.

WHAT CAN WE APPLY FROM GENDER AND WOMEN'S STUDIES TO CLOSE THE PATENTING GENDER GAP?

These "explanations" given by Stephan and El-Ganainy parallel many of the "reasons" elaborated during the last quarter century for why women do not participate in science. Many scholars who study women in science and engineering have suggested solutions or policy initiatives that mentors, departments, and institutions can undertake to attract and retain women in science.

In 1990, I suggested ideas to make science more female-friendly (Rosser 1990). Considering this list makes me wonder if adapting some of these ideas to issues raised about gender and patenting could be useful in attracting more women to commercialization of science. Murray and Graham (2007) suggest policy interventions for faculty PhD advisors, for institutions and their institutional technology transfer offices, and for the industrial and investment communities to facilitate women's participation in commercial science to "ensure that those scientific ideas with important commercial relevance are not squandered" (Murray and Graham 2007, 583). These interventions include suggestions to make certain that commercially active PhD advisors provide women and men students with the same, appropriate mentoring experiences including encouraging all students to look into commercial science, facilitating ties to industrial and other sponsors who want to "buy" their ideas, and demonstrating, especially to women, how to sell their science without violating their scientific integrity. They suggest that institutions appoint more qualified women to high-level administrative positions to encourage industry to look more carefully at their science and leadership capabilities, and appoint them to scientific advisory boards. Technology transfer offices should provide legitimacy and support for women faculty to navigate the commercial science marketplace. After being made aware of the data documenting their leadership role in fostering old boy networks, the industrial and investment community should actively seek out and assess ideas from women, as well as men, scientists.

Using the policy interventions suggested by Murray and Graham, the "explanations" for the gender gap provided by Stephan and El Ganainy, who offer no explicit policy interventions, coupled with evidence of different areas in which women have patented (MacDonald 1992; Frietsch et al. 2007) as a basis, I modified my earlier ideas of ways to make patenting more female-friendly. They are divided into suggestions for faculty, institutions and their technology transfer offices, corporations and venture capitalists, and women scientists.

SUGGESTIONS FOR WOMEN SCIENTISTS

1. Consider expanding your scientific research agenda to include commercialization. This may mean overcoming notions about the purity of what counts as good science.
2. Formulate hypotheses that focus on gender as a crucial part of the commercialization/patenting decision. For example, in initial experimental design, ask whether a particular drug works differently in males and females. Might a drug cure an illness in both men and women or just men? Might an invention be adapted for a new product, especially useful to women?
3. Consider basic research problems that might lead to patents and commercialization of products to help with complex problems more commonly dealt with by women in the home, such as child care-giving, housecleaning, and care for the elderly.
4. Make a conscious effort to broaden networks to include both older and younger men and women scientists.

SUGGESTIONS FOR CORPORATIONS AND VENTURE CAPITALISTS

1. Collect data, disaggregated by gender, on who patents.
2. Expand the scientific research agendas open to commercialization by seeking out the work of women scientists to explore its potential.
3. Explore science and ideas that have not traditionally been considered for commercialization because of gender discounting.
4. Focus on gender as a crucial part of the commercialization/patenting decision. Does a particular drug work differently in males and females or cure an illness in both men and women or just men? Could this invention be adapted for a new product, especially useful to women, children, or the elderly?
5. Include women on scientific advisory boards of corporations.
6. Make a conscious effort to overcome the boys' club atmosphere of commercialization and to broaden networks to include both men and women scientists.
7. Expand recruitment for commercialization ideas beyond males who self-promote very aggressively to include women who may initially appear less entrepreneurial.
8. Move beyond the signal shock stage of only inviting women with very high-level titles such as dean, provost, vice president, or president of the university to serve on scientific advisory boards to seek out women scientists who have not chosen the administrative career path but who have excellent ideas for commercialization.
9. Use national and international conferences to seek out scientific research ideas ripe for commercialization, recognizing that this may be an excellent way to reach women scientists in, particular who are more likely than their male colleagues to live outside one of the geographic hotspots for commercialization.
10. Consider other ways to find ideas for commercialization that rely less on self-promotion and competition with others and more on understanding the potential based upon solid explanation of the science.
11. Make technology transfer and commercialization companies more family-friendly through on-site day care, holding meetings during business hours, and use of conferencing technology to limit necessity for travel.
12. Articulate the goals for commercialization of science to link them directly with making society better and helping people to provide powerful incentives for women to patent.

SUGGESTIONS FOR MALE FACULTY, INSTITUTIONS, AND TECHNOLOGY TRANSFER OFFICES

1. Make transparent all stages of the commercialization process, and provide both male and female students with equal access, mentoring, and connections to each stage of the process.
2. Incorporate discussion of how to build a business plan and how to understand financial risks in commercialization into scientific training for all students, both male and female, just as learning to write grants, build budgets, and manage a laboratory are now considered necessary constituents of graduate training in science and engineering.
3. Encourage all students to undertake research agendas that include some "high-risk" ideas and experiments and some "lower-risk" ideas and experiments. This insures that women have experience with higher-risk ideas and

learn that it's OK to fail. In contrast, some risk-seeking male students may need to learn to balance their high-risk research agenda with the benefits of some lower-risk ideas.

4. Alternate discussion, experiments, and problems assigned between basic and applied science in the classroom and laboratory to facilitate students' perceiving a less sharp dichotomy between science and technology transfer and overcome their aversion to commercialization.
5. Include information from economics, business, and policy, along with science courses in training to socialize students to commercialization and how big science works.
6. Insure that mentoring of students is gender-neutral by inviting all students, both male and female, to explore commercialization potential of their ideas, and by making all parts of the process transparent. Mentoring should also be gender appropriate, in recognizing that women may be more risk averse, less inclined to sell science, and have different constraints, Provide women and men with a variety of approaches to address their particular constraints.
7. Include women in significant administrative positions in the university. This not only provides leadership opportunities and role models for women in the institution, but it also sends the shock signal corporations use to identify women with outstanding credentials.
8. Provide courses and online training and apprenticeship models/ mentors to teach scientists how to sell their ideas to venture capitalists, angel funders, and corporations.
9. Emphasize the social usefulness, especially to help human beings and the environment, of technology transfer and commercialization.

TIMING AND A MODEL TO CLOSE THE GENDER GAP

Why was the gap discovered so recently? Now that we've noticed the gap, when, if ever, will it be closed? How long will it take for women scientists, corporations, venture capitalists, male faculty, technology transfer offices, and institutions to implement the policies others and I have suggested as a way to close this gap? Since the commercialization of science only began to explode in academia in the 1970s and was particularly fueled by the passage of the Bayh-Dole Act in 1980, encouraging academics to claim intellectual property and work with universities to license these rights to firms, in some ways it is not surprising that the "gender gap" has relatively recently been identified (Ding, Murray, and Stuart 2006; Bunker Whittington and Smith-Doerr 2005) and that researchers are only beginning to explore the dimensions of the gap across different fields, sectors, and countries (Ashcraft and Breitzman 2007; Frietsch et al. 2007; Naldi and Prenti 2002, 2004).

To someone like me, who has focused on women in science, women's studies, and curriculum transformation for more than 30 years, it smacks of a familiar pattern: women are excluded until someone "discovers" their absence. Then women become integrated over time in what can be described as a series of stages or phases.

In *Female Friendly Science* (1990), I proposed a five-stage model for curriculum transformation to aid in including more information on women and men of color. Built on models developed by feminist scholars working in other disciplines (McIntosh 1984; Schuster and Van Dyne 1985; Tetreault 1985), the following model is specific for science and mathematics.

Stage 1. Absence of women not noted. This is the traditional approach to science and the curriculum from the perspective of the white, Eurocentric, middle- to upper-class male in which the absence of women is not noted. The assumption is that gender affects neither those who become scientists nor the science produced.

Stage 2. Women as an add-on. This stage recognizes that most scientists are male and that science may reflect a masculine perspective on the physical, natural world. A few exceptional women such as Nobel laureates who have achieved the highest success as defined by the traditional standards of the discipline may be accepted in the scientific community and included in the curriculum.

Stage 3. Women as a problem. Barriers that prevent women from entering science are identified. Women are recognized as a problem, anomaly, or absence from science and the curriculum. Women may be seen as victims, as protesters, or as deprived or defective variants, who deviate from the white, middle- to upper-class norm of the male scientist.

Stage 4. Women as the focus. Women scientists and their unique contributions are sought. The extent to which the role of women has been overlooked, misunderstood, or attributed to male colleagues throughout the history of science is explored to determine women's scientific achievements. Questions are asked about new perspectives that might result when women become the focus in topics chosen for study. New methods may be used and language in which data and theories are described may shift, improving the quality of science.

Stage 5. Inclusive science. Scientists, scientific research, and science curriculum are redefined and reconstructed to include diversity in terms of gender, as well as race, class, age, and other factors.

Thinking of the stage model and its possibilities for explaining phenomena of curriculum drew my attention to the possibility of its application to the gender gap in patents. My junior colleague's interest in the reasons for, and parameters surrounding, the gender gap in patents, coupled with several recent high-profile studies (Ashcraft and Breitzman 2007; Ding et al. 2006; Murray and Graham 2007; Stephan and El Ganainy 2007) which focused on women's low rates of patenting suggest that we are currently moving toward stage 3, centering on barriers or problems that prevent women from patenting. A 2008 article on the dearth of women in high positions in Silicon Valley (Ross 2008) exemplifies the problem stage. The article states that "almost one-third of women at the 'middle-level' of their high-tech careers are planning to quit primarily because of perceived barriers to advancement" (2008).

The time when commercialization and technology transfer began to take off in the late 1970s to the early 1980s until the "discovery" of the gender gap in about 2004–2005 constitutes stage 1, when the absence of women is not noted. Occasional articles highlighting star women who patent at high rates exemplify stage 2, exceptional women who patent at the same rates under the same conditions as men in male-dominated fields. Stephanie Louise Kwolek exemplifies such a stage 2 woman. She invented Kevlar, a synthetic material used in bullet-proof vests that is five times stronger than the same weight of steel, while she worked as a chemist at DuPont and obtained 28 patents during her 40 year career (About. com.Inventors 2006). A recent spate of attention to the gender gap as demonstrated by publications, NSF-funded projects, and conference presentations begins to encroach on stage 4: focus on the gender gap, although it seems unlikely that more than a few individuals have reached stage 4.

In short, most scientists, engineers, and academia have not noticed the gender gap and remain in stage 1. Even individuals involved in technology transfer appear unaware of the absence of women until it is brought to their attention. Once they think about it, they typically agree that very few women patent in the fields with which they are familiar. After some thought, they'll often mention one or two women in their field who do obtain patents, exemplifying stage 2. Most will then begin to move to stage 3 when they wonder what prevents women from patenting at the same rate as men. The 2008 study from Stanford's Clayman Institute and the Anita Borg Institute, titled *Climbing the Technical Ladder: Obstacles and Solutions for Mid-level Women in Technology* (Simard, et al. 2008) highlights the problem aspect of this stage 3.

A gender gap also seems to apply in the recognition of the gender gap in patents. Men and women outside of fields where technology transfer and commercialization occur are equally ignorant of the gender gap in patents. In fields where technology transfer and commercialization are prevalent, men appear much less aware of the gender gap than women. Most women in these same fields are completely aware of the gap and immediately articulate the number of women who patent in their particular area and their personal theories about why women do not patent at the same rate as men. In contrast, men in those same fields typically state that they were unaware of the gap, deny its existence, or declare that it may exist elsewhere but not in their laboratory or department (Rosser 2009).

IMPLICATIONS FOR CLOSING THE GENDER GAP: WHAT ARE THE IMPLICATIONS OF STAGE THEORY FOR TECHNOLOGY TRANSFER? WHAT WILL IT MEAN FOR CLOSING THE GENDER GAP IN PATENTING?

A stage or phase theory implies that the final stage of inclusion won't be reached without taking the time to go through each of the earlier stages. Evidence of narrowing the gender gap among younger cohorts of women suggests progression through the stages. First, the numbers and percentages of women obtaining patents have increased over time. Overall, the U.S. Patent and Trademark Office reports that the percentage of U.S. origin patents in all categories which include at least one woman inventor has increased from 3.7% (1977–1988) to 10.9% in 2002, and that the number of U.S. origin patents that include at least one woman inventor has also been increasing (U.S. Patent and Trademark Office 2003). From 1977 to 2002, women inventors showed the greatest participation in U.S. origin patents in design (11.5%) and plant (11.7%) patenting. By 2002, 12.9% of the design patents and 21.2% of the plant patents had at least one woman inventor. In 2002, 19.6% of chemical utility patents had at least one woman inventor, but electrical (7.0%) and mechanical (7.8%) utility patents with one woman inventor ranked much lower.

Second, younger women are patenting more than senior women colleagues. In a study at "Big School," only 23% of women faculty had patented, while 74% of men faculty held at least one patent. Among the younger cohort the gap is less; in the "entire population of junior faculty, 44% of men have been granted patents compared to only 11% of women" (Murray and Graham 2007).

Third, limited evidence suggests that women are becoming involved with patenting at the same rates as their male peers in some venues. In a study of science-based network firms in the biotechnology industry, Kristin Whittington and Laurel Smith-Doerr (2008) documented that women were as likely as men to become involved in patenting, although the women were still patenting less frequently than the men.

Overall, both nationally and internationally, the gender gap in patents has shown some signs of closing over time. These studies provide some evidence for progression through the stages. Reaching stage 5 of inclusion seems distant, although some fields and sectors, such as the biotech startups, appear to be closer to inclusion.

In order to reach inclusion (stage 5), not only will all disciplines, but all sectors and individuals involved, have to pass through these stages. As I worked in projects on curricular transformation occurring in the sciences, I recognized that the phases applied to more than curriculum. These stages describe steps of personal development through which individuals progress as they become aware of biases due to gender and race in curriculum and pedagogy. In an early book (Rosser 1986), I suggested that an individual must progress personally through, or at least to, a stage of development before he or she can develop curriculum and pedagogical techniques at that stage. For example, a faculty member cannot teach a stage 5, inclusive course in which the primary focus shifts from the white male experience to include women, men of color, and disabled persons, if she or he is only at the add-on phase (stage 2) in her or his own thinking.

Just as phase theory may be applied to personal development and transformation toward inclusion as well as curriculum, it also may be applied to programs, departments, institutions, and/or agencies. As is the case with individuals, even with a well-conceived (stage 5) plan for diversity, and inclusion and the best of intentions on the part of all faculty, staff, and/or employees, a university cannot jump from stage 1 to 5 without going through the intermediate stages. Moving an entire department and curriculum toward gender inclusion is difficult. Transforming an entire college or university has proved a long-term challenge.

Technology transfer and commercialization involve interactions with many individuals outside the university from a variety of sectors with quite different cultures from that of academia. Corporations and their boards, venture capitalists, marketing specialists, and angel funders, in addition to students, men and women faculty, and technology transfer personnel in universities will all need to progress through these stages to close the gender gap. Not only is the group involved in technology transfer very large and diverse in terms of backgrounds and expertise, but different components and individuals hold competing interests and cultures.

More significant than understanding the stage theory and process is the desire of each individual and each group, as well as that of corporate power and elite educational institutions, to want to close the gender gap. Since technology transfer and patenting involve substantial amounts of money, such a desire cannot be taken for granted. Indeed, one study of the gender gap noted that part of the appeal of technology transfer for some academics may have been to create an elite male-only club: As Stephan and EI-Ganainy suggest, "entrepreneurial science opened the possibility of having a 'boys' club' when it emerged on campuses in the late 1970s" just at the time when larger numbers of women and underrepresented minorities were entering academic science (Stephan and El-Ganainy 2007, 486).

Aside from the obvious issues of fairness and discrimination, what other problems and losses result from the boys' club that excludes women and leads to a gender gap in patenting? First, women who are scientists lose. Studies (Stephan and El-Ganainy 2007) document that women scientists, compared to their male peers, have fewer graduate students and postdocs and smaller, less diverse collegial networks. Compared to their male peers, women are asked less frequently to consult or serve on scientific advisory boards, and have their work discounted more frequently by industry (Murray and Graham 2007). This means that women scientists lose out not only on higher salaries, stock options, awards, and promotions, but also on opportunities to work in some of the most cutting-edge fields on the frontiers of science such as information technology, biotechnology, and nanotechnology.

Second, science loses in attracting more individuals with creative ideas. Fewer women are attracted to science because of the perceived chilly atmosphere of exclusion (Rosser 2004). As indicated in the recent Clayman Institute and Anita Borg Study (Simard et al. 2008), perceived barriers and obstacles cause women either to not enter the field, to drop out, or to switch fields mid-career.

Third, society loses because fewer products are developed. Having very few women obtaining patents hurts scientific innovation, technology, and competitiveness overall. Although men dominate patenting in all fields, some relative gender differences in fields of patents exist. Since ideas for patents often arise in areas with which the innovators have experiences, small numbers of women patenting suggests fewer products to solve problems and facilitate daily life for women and children in particular. If more women were involved in commercialization, imagine the new, useful products to benefit society that might be developed. Simultaneously, increasing the percentage of women scientists and engineers who patent is also likely to increase their economic equality as technology transfer and commercialization of science increase in the United States and globally.

In contrast, if the percentage of patents awarded to women remains far lower than the percentage of women scientists and engineers in the science, engineering, technology, and mathematics (STEM) workforce, this may represent another example of old wine in new bottles. Does exclusion of women from these leading-edge fields in innovation simply represent the twenty-first century version of the mid-twentieth-century phenomenon of women not holding major leadership positions in big science? Such exclusion represents a major loss, since women scientists have focused on different problems, used new approaches, and produced new theoretical perspectives that have benefitted science, technology, and society.

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SECTION II

Feminist Approaches in/to Science and Technology

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CHAPTER 9

Sex and Death in the Rational World of Defense Intellectuals

Carol Cohn

"I can't believe *that*," said Alice.

"Can't you?" the Queen said in a pitying tone. "Try again: draw a long breath, and shut your eyes."

Alice laughed. "There's no use trying," she said. "One *can't* believe impossible things."

"I daresay you haven't had much practice," said the Queen. "When I was your age, I always did it for half-an-hour a day. Why, sometimes I've believed as many as six impossible things before breakfast." [LEWIS CARROLL, *Through the Looking Glass*]

My close encounter with nuclear strategic analysis started in the summer of 1984. I was one of forty-eight college teachers (one often women) attending a summer workshop on nuclear weapons, nuclear strategic doctrine, and arms control, taught by distinguished "defense intellectuals." Defense intellectuals are men (and indeed, they are virtually all men) "who use the concept of deterrence to explain why it is safe to have weapons of a kind and number it is not safe to use."[1] They are civilians who move in and out of government, working sometimes as administrative officials or consultants, sometimes at universities and think tanks. They formulate what they call "rational" systems for dealing with the problems created by nuclear weapons: how to manage the arms race; how to deter the use of nuclear weapons; how to fight a nuclear war if deterrence fails. It is their calculations that are used to explain the necessity of having nuclear destructive capability at what George Kennan has called "levels of such grotesque dimensions as to defy rational understanding."[2] At the same time, it is their reasoning that is used to explain why it is not safe to live without nuclear weapons.[3] In short, they create the theory that informs and legitimates American nuclear strategic practice.

For two weeks, I listened to men engage in dispassionate discussion of nuclear war. I found myself aghast, but morbidly fascinated—not by nuclear weaponry, or by images of nuclear destruction, but by the extraordinary abstraction and removal from what I knew as reality that characterized the professional discourse. I became obsessed by the question, How can they think this way? At the end of the summer program, when I was offered the opportunity to stay on at the university's center on defense technology and arms control (hereafter known as "the Center"), I jumped at the chance to find out how they could think "this" way.

I spent the next year of my life immersed in the world of defense intellectuals. As a participant observer, I attended lectures, listened to arguments, conversed with defense analysts, and interviewed graduate students at the beginning, middle, and end of their training. I learned their specialized language, and I tried to understand what they thought and how they thought. I sifted through their logic for its internal inconsistencies and its unspoken assumptions. But as I learned their language, as I became more and more engaged with their information and their arguments, I found that my own thinking was changing. Soon, I could no longer cling to the comfort of studying an external and objectified "them." I had to confront a new question: How can I think this way? How can any of us?

Throughout my time in the world of strategic analysis, it was hard not to notice the ubiquitous weight of gender, both in social relations and in the language itself; it is an almost entirely male world (with the exception of the secretaries), and the language contains many rather arresting metaphors.

There is, of course, an important and growing body of feminist theory about gender and language.[4] In addition, there is a rich and increasingly vast body of theoretical work exploring the gendered aspects of war and militarism, which examines such issues as men's and women's different relations to militarism and pacifism, and the ways in which gender ideology is used in the service of militarization. Some of the feminist work on gender and war is also part of an emerging, powerful feminist critique of ideas of rationality as they have developed in Western culture.[5] While I am indebted to all of these bodies of work, my own project is most closely linked to the development of feminist critiques of dominant Western concepts of reason. My goal is to discuss the nature of nuclear strategic thinking; in particular, my emphasis is on the role of its specialized language, a language that I call "technostrategic."[6] I have come to believe that this language both reflects and shapes the nature of the American nuclear strategic project, that it plays a central role in allowing defense intellectuals to think and act as they do, and that feminists who are concerned about nuclear weaponry and nuclear war must give careful attention to the language we choose to use—whom it allows us to communicate with and what it allows us to think as well as say.

STATE I: LISTENING

Clean Bombs and Clean Language

Entering the world of defense intellectuals was a bizarre experience—bizarre because it is a world where men spend their days calmly and matter-of-factly discussing nuclear weapons, nuclear strategy, and nuclear war. The discussions are carefully and intricately reasoned, occurring seemingly without any sense of horror, urgency, or moral outrage—in fact, there seems to be no graphic reality behind the words, as they speak of "first strikes," "counterforce exchanges," and "limited nuclear war," or as they debate the comparative values of a "minimum deterrent posture" versus a "nuclear war-fighting capability."

Yet what is striking about the men themselves is not, as the content of their conversations might suggest, their cold-bloodedness. Rather, it is that they are a group of men unusually endowed with charm, humor, intelligence, concern, and decency. Reader, I liked them. At least, I liked many of them. The attempt to understand how such men could contribute to an endeavor that I see as so fundamentally destructive became a continuing obsession for me, a lens through which I came to examine all of my experiences in their world.

In this early stage, I was gripped by the extraordinary language used to discuss nuclear war. What hit me first was the elaborate use of abstraction and euphemism, of words so bland that they never forced the speaker or enabled the listener to touch the realities of nuclear holocaust that lay behind the words.

Anyone who has seen pictures of Hiroshima burn victims or tried to imagine the pain of hundreds of glass shards blasted into flesh may find it perverse beyond imagination to hear a class of nuclear devices matter-of-factly referred to as "clean bombs." "Clean bombs" are nuclear devices that are largely fusion rather than fission and that therefore release a higher quantity of energy, not as radiation, but as blast, as destructive explosive power.[7]

"Clean bombs" may provide the perfect metaphor for the language of defense analysts and arms controllers. This language has enormous destructive power, but without emotional fallout, without the emotional fallout that would result if it were clear one was talking about plans for mass murder, mangled bodies, and unspeakable human suffering. Defense analysts talk about "countervalue attacks" rather than about incinerating cities. Human death, in nuclear parlance, is most often referred to as "collateral damage"; for, as one defense analyst said wryly, "The Air Force doesn't target people, it targets shoe factories."[8]

Some phrases carry this cleaning-up to the point of inverting meaning. The MX missile will carry ten warheads, each with the explosure power of 300–475 kilotons of TNT: one missile the bearer of destruction approximately 250–400 times that of the Hiroshima bombing.[9] Ronald Reagan has dubbed the MX missile "the Peacekeeper." While this renaming was the object of considerable scorn in the community of defense analysts, these very same analysts refer to the MX as a "damage limitation weapon."[10]

These phrases, only a few of the hundreds that could be discussed, exemplify the astounding chasm between image and reality that characterizes technostrategic language. They also hint at the terrifying way in which the existence of nuclear devices has distorted our perceptions and redefined the world. "Clean bombs" tells us that radiation is the only "dirty" part of killing people.

To take this one step further, such phrases can even seem healthful/curative/corrective. So that we not only have "clean bombs" but also "surgically clean strikes" ("counterforce" attacks that can purportedly "take out"—i.e., accurately destroy—an opponent's weapons or command centers without causing significant injury to anything else). The image of excision of the offending weapon is unspeakably ludicrous when the surgical tool is not a delicately controlled scalpel but a nuclear warhead. And somehow it seems to be forgotten that even scalpels spill blood.[11]

White Men in Ties Discussing Missile Size

Feminists have often suggested that an important aspect of the arms race is phallic worship, that "missile envy" is a significant motivating force in the nuclear build-up.[12] I have always found this an uncomfortably reductionist explanation and hoped that my research at the Center would yield a more complex analysis. But still, I was curious about the extent to which I might find a sexual subtext in the defense professionals' discourse. I was not prepared for what I found.

I think I had naively imagined myself as a feminist spy in the house of death—that I would need to sneak around and eavesdrop on what men said in unguarded moments, using all my subtlety and cunning to unearth whatever sexual imagery might be underneath how they thought and spoke. I had naively believed that these men, at least in public, would appear to be aware of feminist critiques. If they had not changed their language, I thought that at least at some point in a long talk about "penetration aids," someone would suddenly look up, slightly embarrassed to be caught in such blatant confirmation of feminist analyses of What's Going On Here.[13]

Of course, I was wrong. There was no evidence that any feminist critiques had ever reached the ears, much less the minds, of these men. American military dependence on nuclear weapons was explained as "irresistible, because you get more bang for the buck." Another lecturer solemnly and scientifically announced "to disarm is to get rid of all your stuff." (This may, in turn, explain why they see serious talk of nuclear disarmament as perfectly resistable, not to mention foolish. If disarmament is emasculation, how could any real man even consider it?) A professor's explanation of why the MX missile is to be placed in the silos of the newest Minuteman missiles, instead of replacing the older, less accurate ones, was "because they're in the nicest hole—you're not going to take the nicest missile you have and put it in a crummy hole." Other lectures were filled with discussion of vertical erector launchers, thrust-to-weight ratios, soft lay downs, deep penetration, and the comparative advantages of protracted versus spasm attacks—or what one military adviser to the National Security Council has called "releasing 70 to 80 percent of our megatonnage in one orgasmic whump."[14] There was serious concern about the need to harden our missiles and the need to "face it, the Russians are a little harder than we are." Disbelieving glances would occasionally pass between me and my one ally in the summer program, another woman, but no one else seemed to notice.

If the imagery is transparent, its significance may be less so. The temptation is to draw some conclusions about the defense intellectuals themselves—about what they are *really* talking about, or their motivations; but the temptation is worth resisting. Individual motivations cannot necessarily be read directly from imagery; the imagery itself does not originate in these particular individuals but in a broader cultural context.

Sexual imagery has, of course, been a part of the world of warfare since long before nuclear weapons were even a gleam in a physicist's eye. The history of the atomic bomb project itself is rife with overt images of competitive male sexuality, as is the discourse of the early nuclear physicists, strategists, and SAC commanders.[15] Both the military itself and the arms manufacturers are constantly exploiting the phallic imagery and promise of sexual domination that their weapons so conveniently suggest. A quick glance at the publications that constitute some of the research sources for defense intellectuals makes the depth and pervasiveness of the imagery evident.

Air Force Magazine's advertisements for new weapons, for example, rival *Playboy* as a catalog of men's sexual anxieties and fantasies. Consider the following, from the June 1985 issue: emblazoned in bold letters across the top of a two-page advertisement for the AV-8B Harrier 11—"Speak Softly and Carry a Big Stick." The copy below boasts "an exceptional thrust to weight ratio" and "vectored thrust capability that makes the . . . unique rapid response possible." Then, just in case we've failed to get themes sage, the last line reminds us, "Just the sort of 'Big Stick' Teddy Roosevelt had in mind way back in 1901."[16]

An ad for the BKEP (BLU-106/B) reads:

> The Only Way to Solve Some Problems is to Dig Deep.
>
> THE BOMB, KINETIC ENERGY PENETRATOR
>
> "Will provide the tactical air commander with efficient power to deny or significantly delay enemy airfield operations."
>
> "Designed to maximize runway cratering by optimizing penetration dynamics and utilizing the most efficient warhead yet designed."[17]

(In case the symbolism of "cratering" seems far-fetched, I must point out that I am not the first to see it. The French use the

Mururoa Atoll in the South Pacific for their nuclear tests and assign a woman's name to each of the craters they gouge out of the earth.)

Another, truly extraordinary, source of phallic imagery is to be found in descriptions of nuclear blasts themselves. Here, for example, is one by journalist William Laurence, who was brought to Nagasaki by the Air Force to witness the bombing. "Then, just when it appeared as though the thing had settled down in to a state of permanence, there came shooting out of the top a giant mushroom that increased the size of the pillar to a total of 45,000 feet. The mushroom top was even more alive than the pillar, seething and boiling in a white fury of creamy foam, sizzling upward and then descending earthward, a thousand geysers rolled into one. It kept struggling in an elemental fury, like a creature in the act of breaking the bonds that held it down."[18]

Given the degree to which it suffuses their world, that defense intellectuals themselves use a lot of sexual imagery does not seem especially surprising. Nor does it, by itself, constitute grounds for imputing motivation. For me, the interesting issue is not so much the imagery's psychodynamic origins, as how it functions. How does it serve to make it possible for strategic planners and other defense intellectuals to do their macabre work? How does it function in their construction of a work world that feels tenable? Several stories illustrate the complexity.

During the summer program, a group of us visited the New London Navy base where nuclear submarines are homeported and the General Dynamics Electric Boat boatyards where a new Trident submarine was being constructed. At one point during the trip we took a tour of a nuclear powered submarine. When we reached the part of the sub where the missiles are housed, the officer accompanying us turned with a grin and asked if we wanted to stick our hands through a hole to "pat the missile." *Pat the missile?*

The image reappeared the next week, when a lecturer scornfully declared that the only real reason for deploying cruise and Pershing II missiles in Western Europe was "so that our allies can pat them." Some months later, another group of us went to be briefed at NORAD (the North American Aerospace Defense Command). On the way back, our plane went to refuel at Offut Air Force Base, the Strategic Air Command head quarters near Omaha, Nebraska. When word leaked out that our landing would be delayed because the new B-1 bomber was in the area, the plane became charged with a tangible excitement that built as we flew in our holding pattern, people craning their necks to try to catch a glimpse of the B-1 in the skies, and climaxed as we touched down on the runway and hurtled past it. Later, when I returned to the Center I encountered a man who, unable to go on the trip, said to me enviously, "I hear you got to pat a B-1."

What is all this "patting"? What are men doing when they "pat" these high-tech phalluses? Patting is an assertion of intimacy, sexual possession, affectionate domination. The thrill and pleasure of "patting the missile" is the proximity of all that phallic power, the possibility of vicariously appropriating it as one's own.

But if the predilection for patting phallic objects indicates something of the homoerotic excitement suggested by the language, it also has another side. For patting is not only an act of sexual intimacy. It is also what one does to babies, small children, the pet dog. One pats that which is small, cute, and harmless—not terrifyingly destructive. Pat it, and its lethality disappears.

Much of the sexual imagery I heard was rife with the sort of ambiguity suggested by "patting the missiles." The imagery can be construed as a deadly serious display of the connections between masculine sexuality and the arms race. At the same time, it can also be heard as a way of minimizing the seriousness of militarist endeavors, of denying their deadly consequences. A former Pentagon target analyst, in telling me why he thought plans for "limited nuclear war" were ridiculous, said, "Look, you gotta understand that it's a pissing contest—you gotta expect them to use every thing they've got." What does this image say? Most obviously, that this is all about competition for manhood, and thus there is tremendous danger. But at the same time, the image diminishes the contest and its outcomes, by representing it as an act of boyish mischief.

Fathers, Sons, and Virgins

"Virginity" also made frequent, arresting, appearances in nuclear dis course. In the summer program, one professor spoke of India's explosion of a nuclear bomb as "losing her virginity"; the question of how the United States should react was posed as whether or not we should "throw her away." It is a complicated use of metaphor. Initiation into the nuclear world involves being deflowered, losing one's innocence, knowing sin, all wrapped up into one. Although the manly United States is no virgin, and proud of it, the double standard raises its head in the question of whether or not a woman is still worth anything to a man once she has lost her virginity.

New Zealand's refusal to allow nuclear-armed or nuclear-powered warships into its ports prompted similar reflections on virginity. A good example is provided by Retired U.S. Air Force General Ross Milton's angry column in *Air Force Magazine*, entitled, "Nuclear Virginity." His tone is that of a man whose advances have been spurned. He is contemptuous of the woman's protestation that she wants to remain pure, innocent of nuclear weapons; her moral reluctance is a quaint and ridiculous throw back. But beyond contempt, he also feels outraged—after all, this is a woman we have *paid* for, who *still* will not come across. He suggests that we withdraw our goods and services—and then we will see just how long she tries to hold onto her virtue.[19] The patriarchal bargain could not be laid out more clearly.

Another striking metaphor of patriarchal power came early in the summer program, when one of the faculty was giving a lecture on deterrence. To give us a concrete example from outside the world of military strategy, he described having a seventeen-year-old son of whose TV watching habits he disapproves. He deals with the situation by threatening to break his son's arm if he turns on the TV again. "That's deterrence!" he said triumphantly.

What is so striking about this analogy is that at first it seems so inappropriate. After all, we have been taught to believe that nuclear deterrence is a relation between two countries of more or less equal strength, in which one is only able to deter the other from doing it great harm by threatening to do the same in return. But in this case, the partners are unequal, and the stronger one is using his superior force not to protect himself or others from grave injury but to coerce.

But if the analogy seems to be a flawed expression of deterrence as we have been taught to view it, it is nonetheless extremely revealing about U.S. nuclear deterrence as an operational, rather than rhetorical or declaratory policy. What it suggests is the speciousness of the defensive rhetoric that surrounds deterrence—of the idea that we face an implacable enemy and that we stockpile nuclear weapons only in an attempt to defend ourselves. Instead, what we see is the drive to superior power as a means to exercise one's will and a readiness to threaten the disproportionate use of force in order to achieve one's own ends. There is no question here of recognizing competing but legitimate needs, no desire to negotiate, dis cuss, or compromise, and most important, no necessity for that recognition or desire, since the father carries the bigger stick.[20]

The United States frequently appeared in discussions about international politics as "father," sometimes coercive, sometimes benevolent, but always knowing best. The single time that any mention was made of countries other than the United States, our NATO allies, or the USSR was in a lecture on nuclear proliferation. The point was made that younger countries simply could not be trusted to know what was good for them, nor were they yet fully responsible, so nuclear weapons in their hands would be much more dangerous than in ours. The metaphor used was that of parents needing to set limits for their children.

Domestic Bliss

Sanitized abstraction and sexual and patriarchal imagery, even if disturbing, seemed to fit easily into the masculinist world of nuclear war planning. What did not fit, what surprised and puzzled me most when I first heard it, was the set of metaphors that evoked images that can only be called domestic.

Nuclear missiles are based in "silos." On a Trident submarine, which carries twenty-four multiple warhead nuclear missiles, crew members call the part of the submarine where the missiles are lined up in their silos ready for launching "the Christmas tree farm." What could be more bucolic—farms, silos, Christmas trees?

In the ever-friendly, even romantic world of nuclear weaponry, enemies "exchange" warheads; one missile "takes out" another; weapons systems can "marry up"; "coupling" is sometimes used to refer to the wiring between mechanisms of warning and response, or to the psycho political links between strategic (intercontinental) and theater (European based) weapons. The patterns in which a MIRVed missile's nuclear war heads land is known as a "footprint. "[21] These nuclear explosives are not dropped; a "bus" "delivers" them. In addition, nuclear bombs are not referred to as bombs or even warheads; they are referred to as "reentry vehicles," a term far more bland and benign, which is then shortened to "RVs," a term not only totally abstract and removed from the reality of a bomb but also resonant with the image of the recreational vehicles of the ideal family vacation.

These domestic images must be more than simply one more form of distancing, one more way to remove oneself from the grisly reality behind the words; ordinary abstraction is adequate to that task. Something else, something very peculiar, is going on here. Calling the pattern in which bombs fall a "footprint" almost seems a willful distorting process, a playful, perverse refusal of accountability—because to be accountable to reality is to be unable to do this work.

These words may also serve to domesticate, to tame the wild and uncontrollable forces of nuclear destruction. The metaphors minimize; they are a way to make phenomena that are beyond what the mind can encompass smaller and safer, and thus they are a way of gaining mastery over the unmasterable. The fire-breathing dragon under the bed, the one who threatens to incinerate your family, your town, your planet, becomes a pet you can pat.

Using language evocative of everyday experiences also may simply serve to make the nuclear strategic community more comfortable with what they are doing. "PAL" (permissive action links) is the carefully constructed, friendly acronym for the electronic system designed to pre vent the unauthorized firing of nuclear warheads. "BAMBI" was the acronym developed for an early version of an antiballistic missile system (for Ballistic Missile Boost Intercept). The president's

Annual Nuclear Weapons Stockpile Memorandum, which outlines both short- and long range plans for production of new nuclear weapons, is benignly referred to as "the shopping list." The National Command Authorities choose from a "menu of options" when deciding among different targeting plans. The "cookie cutter" is a phrase used to describe a particular model of nuclear attack. Apparently it is also used at the Department of Defense to refer to the neutron bomb.[22]

The imagery that domesticates, that humanizes insentient weapons, may also serve, paradoxically, to make it all right to ignore sentient human bodies, human lives.[23] Perhaps it is possible to spend one's time thinking about scenarios for the use of destructive technology and to have human bodies remain invisible in that technological world precisely because that world itself now *includes* the domestic, the human, the warm, and playful—the Christmas trees, the RVs, the affectionate pats. It is a world that is in some sense complete unto itself; it even includes death and loss. But it is weapons, not humans, that get "killed." "Fratricide" occurs when one of your warheads "kills" another of your own warheads. There is much discussion of "vulnerability" and "survivability," but it is about the vulnerability and survival of weapons systems, not people.

Male Birth and Creation

There is one set of domestic images that demands separate attention images that suggest men's desire to appropriate from women the power of giving life and that conflate creation and destruction. The bomb project is rife with images of male birth.[24] In December 1942, Ernest Lawrence's telegram to the physicists at Chicago read, "Congratulations to the new parents. Can hardly wait to see the new arrival."[25] At Los Alamos, the atom bomb was referred to as "Oppenheimer's baby." One of the physicists working at Los Alamos, Richard Feynman, writes that when he was temporarily on leave after his wife's death, he received a telegram saying, "The baby is expected on such and such a day."[26] At Lawrence Livermore, the hydrogen bomb was referred to as "Teller's baby," although those who wanted to disparage Edward Teller's contribution claimed he was not the bomb's father but its mother. They claimed that Stanislaw Ulam was the real father; he had the all important idea and inseminated Teller with it. Teller only "carried it" after that.[27]

Forty years later, this idea of male birth and its accompanying belittling of maternity—the denial of women's role in the process of creation and the reduction of "motherhood" to the provision of nurturance (apparently Teller did not need to provide an egg, only a womb)—seems thoroughly incorporated into the nuclear mentality, as I learned on a subsequent visit to U.S. Space Command in Colorado Springs. One of the briefings I attended included discussion of a new satellite system, the not yet "on line" MILSTAR system.[28] The officer doing the briefing gave an excited recitation of its technical capabilities and then an explanation of the new Unified Space Command's role in the system. Self-effacingly he said, "We'll do the motherhood role—telemetry, tracking, and control—the maintenance."

In light of the imagery of male birth, the extraordinary names given to the bombs that reduced Hiroshima and Nagasaki to ash and rubble—"Little Boy" and "Fat Man"—at last become intelligible. These ultimate destroyers were the progeny of the atomic scientists—and emphatically not just any progeny but male progeny. In early tests, before they were certain that the bombs would work, the scientists expressed their concern by saying that they hoped the baby was a boy, not a girl—that is, not a dud.[29] General Grove's triumphant cable to Secretary of War Henry Stimson at the Potsdam conference, informing him that the first atomic bomb test was successful read, after decoding: "Doctor has just returned most enthusiastic and confident that the little boy is as husky as his big brother. The light in his eyes discernible from here to Highhold and I could have heard his screams from here to my farm."[30] Stimson, in turn, informed Churchill by writing him a note that read, "Babies satisfactorily born."[31] In 1952, Teller's exultant telegram to Los Alamos announcing the successful test of the hydrogen bomb, "Mike," at Eniwetok Atoll in the Marshall Islands, read, "It's a boy."[32] The nuclear scientists gave birth to male progeny with the ultimate power of violent domination over female Nature. The defense intellectuals' project is the creation of abstract formulations to control the forces the scientists created—and to participate thereby in their world-creating/destroying power.

The entire history of the bomb project, in fact, seems permeated with imagery that confounds man's overwhelming technological power to destroy nature with the power to create—imagery that inverts men's destruction and asserts in its place the power to create new life and a new world. It converts men's destruction into their rebirth.

William L. Laurence witnessed the Trinity test of the first atomic bomb and wrote: "The big boom came about a hundred seconds after the great flash—the first cry of a new-born world. . . . They clapped their hands as they leaped from the ground—earthbound man symbolising the birth of a new force."[33] Watching "Fat Man" being assembled the day before it was dropped on Nagasaki, he described seeing the bomb as "being fashioned into a living thing."[34] Decades later, General Bruce K. Holloway, the commander in chief of the Strategic Air Command from 1968 to 1972, universe."[35]

God and the Nuclear Priesthood

The possibility that the language reveals an attempt to appropriate ultimate creative power is evident in another striking aspect of the language of nuclear weaponry and doctrine—the religious imagery. In a subculture of hard-nosed realism and hyper-rationality, in a world that claims as a sign of its superiority its vigilant purging of all nonrational elements, and in which people carefully excise from their discourse every possible trace of soft sentimentality, as though purging dangerous nonsterile elements from a lab, the last thing one might expect to find is religious imagery—imagery of the forces that science has been defined in *opposition to*. For surely, given that science's identity was forged by its separation from, by its struggle for freedom from, the constraints of religion, the only thing as unscientific as the female, the subjective, the emotional, would be the religious. And yet, religious imagery permeates the nuclear past and present. The first atomic bomb test was called Trinity—the unity of the Father, the Son, and the Holy Spirit, the male forces of Creation. The imagery is echoed in the language of the physicists who worked on the bomb and witnessed the test: "It was as though we stood at the first day of creation." Robert Oppenheimer thought of Krishna's words to Arjuna in the *Bhagavad Gita*: "I am become Death, the Shatterer of Worlds."[36]

Perhaps most astonishing of all is the fact that the creators of strategic doctrine actually refer to members of their community as "the nuclear priesthood." It is hard to decide what is most extraordinary about this: the easy arrogance of their claim to the virtues and supernatural power of the priesthood; the tacit admission (*never* spoken directly) that rather than being unflinching, hard-nosed, objective, empirically minded scientific describers of reality, they are really the creators of dogma; or the extraordinary implicit statement about who, or rather what, has become god. If this new priesthood attains its status through an inspired knowledge of nuclear weapons, it gives a whole new meaning to the phrase "a mighty fortress is our God."

STAGE 2: LEARNING TO SPEAK THE LANGUAGE

Although I was startled by the combination of dry abstraction and counterintuitive imagery that characterizes the language of defense intellectuals, my attention and energy were quickly focused on decoding and learning to speak it. The first task was training the tongue in the articulation of acronyms.

Several years of reading the literature of nuclear weaponry and strategy had not prepared me for the degree to which acronyms littered all conversations, nor for the way in which they are used. Formerly, I had thought of them mainly as utilitarian. They allow you to write or speak faster. They act as a form of abstraction, removing you from the reality behind the words. They restrict communication to the initiated, leaving all others both uncomprehending and voiceless in the debate.

But, being at the Center, hearing the defense analysts use the acronyms, and then watching as I and others in the group started to fling acronyms around in our conversation revealed some additional, unexpected dimensions.

First, in speaking and hearing, a lot of these terms can be very sexy. A small supersonic rocket "designed to penetrate any Soviet air defense" is called a SRAM (for short-range attack missile). Submarine-launched cruise missiles are not referred to as SLCMs, but "slick'ems." Ground-launched cruise missiles are "glick'ems." Air-launched cruise missiles are not sexy but magical—"alchems" (ALCMs) replete with the illusion of turning base metals into gold.

TACAMO, the acronym used to refer to the planes designed to provide communications links to submarines, stands for "take charge and move out." The image seems closely related to the nicknames given to the new guidance systems for "smart weapons"—" shoot and scoot" or "fire and forget."

Other acronyms work in other ways. The plane in which the president supposedly will be flying around above a nuclear holocaust, receiving intelligence and issuing commands for the next bombing, is referred to as "kneecap" (for NEACP—National Emergency Airborne Command Post). The edge of derision suggested in referring to it as "kneecap" mirrors the edge of derision implied when it is talked about at all, since few believe that the president really would have the time to get into it, or that the communications systems would be working if he were in it, and some might go so far as to question the usefulness of his being able to direct an extended nuclear war from his kneecap even if it were feasible. (I never heard the morality of this idea addressed.) But it seems to me that speaking about it with that edge of derision is *exactly* what allows it to be spoken about and seriously discussed at all. It is the very ability to make fun of a concept that makes it possible to work with it rather than reject it outright.

In other words, what I learned at the program is that talking about nuclear weapons is fun. I am serious. The words are fun to say; they are racy, sexy, snappy. You can throw them around in rapid-fire succession. They are quick, clean, light; they trip off the tongue. You can reel off dozens of them in seconds, forgetting about how one might just interfere with the next, not to mention with the lives beneath them.

I am not describing a phenomenon experienced only by the perverse, although the phenomenon itself may be perverse indeed. Nearly everyone I observed clearly took pleasure in using the words.

It mattered little whether we were lecturers or students, hawks or doves, men or women we all learned it, and we all spoke it. Some of us may have spoken with a self-consciously ironic edge, but the pleasure was there nonetheless.

Part of the appeal was the thrill of being able to manipulate an arcane language, the power of entering the secret kingdom, being someone in the know. It is a glow that is a significant part of learning about nuclear weaponry. Few know, and those who do are powerful. You can rub elbows with them, perhaps even be one yourself.

That feeling, of course, does not come solely from the language. The whole set-up of the summer program itself, for example, communicated the allures of power and the benefits of white male privileges. We were provided with luxurious accommodations, complete with young black women who came in to clean up after us each day; generous funding paid not only our transportation and food but also a large honorarium for attending; we met in lavishly appointed classrooms and lounges. Access to excellent athletic facilities was guaranteed by a "Temporary Privilege Card," which seemed to me to sum up the essence of the experience. Perhaps most important of all were the endless allusions by our lecturers to "what I told John [Kennedy]" and "and then Henry [Kissinger] said," or the lunches where we could sit next to a prominent political figure and listen to Washington gossip.

A more subtle, but perhaps more important, element of learning the language is that, when you speak it, you feel in control. The experience of mastering the words infuses your relation to the material. You can get so good at manipulating the words that it almost feels as though the whole thing is under control. Learning the language gives a sense of what I would call cognitive mastery; the feeling of mastery of technology that is finally not controllable but is instead powerful beyond human comprehension, powerful in a way that stretches and even thrills the imagination.

The more conversations I participated in using this language, the less frightened I was of nuclear war. How can learning to speak a language have such a powerful effect? One answer, I believe, is that the *process* of learning the language is itself a part of what removes you from the reality of nuclear war.

I entered a world where people spoke what amounted to a foreign language, a language I had to learn if we were to communicate with one another. So I became engaged in the challenge of it—of decoding the acronyms and figuring out which were the proper verbs to use. My focus was on the task of solving the puzzles, developing language competency not on the weapons and wars behind the words. Although my interest was in thinking about nuclear war and its prevention, my energy was else where.

By the time I was through, I had learned far more than a set of abstract words that refers to grisly subjects, for even when the subjects of a standard English and nuke-speak description seem to be the same, they are, in fact, about utterly different phenomena. Consider the following descriptions, in each of which the subject is the aftermath of a nuclear attack:

> Everything was black, had vanished into the black dust, was destroyed. Only the flames that were beginning to lick their way up had any color. From the dust that was like a fog, figures began to loom up, black, hairless, faceless. They screamed with voices that were no longer human. Their screams drowned out the groans rising everywhere from the rubble, groans that seemed to rise from the very earth itself.[37]

> [You have to have ways to maintain communications in a] nuclear environment, a situation bound to include EMP blackout, brute force damage to systems, a heavy jamming environment, and so on.[38]

There are no ways to describe the phenomena represented in the first with the language of the second. Learning to speak the language of defense analysts is not a conscious, cold-blooded decision to ignore the effects of nuclear weapons on real live human beings, to ignore the sensory, the emotional experience, the human impact. It is simply learning a new language, but by the time you are through, the content of what you can talk about is monumentally different, as is the perspective from which you speak.

In the example above, the differences in the two descriptions of a "nuclear environment" stem partly from a difference in the vividness of the words themselves—the words of the first intensely immediate and evocative, the words of the second abstract and distancing. The passages also differ in their content; the first describes the effects of a nuclear blast on human beings, the second describes the impact of a nuclear blast on technical systems designed to assure the "command and control" of nuclear weapons. Both of these differences may stem from the difference of perspective: the speaker in the first is a victim of nuclear weapons, the speaker in the second is a user. The speaker in the first is using words to try to name and contain the horror of human suffering all around her; the speaker in the second is using words to ensure the possibility of launching the next nuclear attack. Technostrategic language can be used only to articulate the perspective of the users of nuclear weapons, not that of the victims.[39]

Thus, speaking the expert language not only offers distance, a feeling of control, and an alternative focus for one's energies; it also offers escape—escape from thinking of oneself as a victim of nuclear war. I do not mean this on the level of individual consciousness; it is not that defense analysts somehow convince themselves that they would not be among the victims of nuclear war, should it occur. But I do mean it in terms of the structural position the speakers of the language occupy and the perspective they get from that position. *Structurally*, speaking technostrategic language re moves them from the position of victim and puts them in the position of the planner, the user, the actor. From that position, there is neither need nor way to see oneself as a victim; no matter what one deeply knows or believes about the likelihood of nuclear war, and no matter what sort of terror or despair the knowledge of nuclear war's reality might inspire, the speakers of technostrategic language are positionally allowed, even forced, to escape that awareness, to escape viewing nuclear war from the position of the victim, by virtue of their linguistic stance as users, rather than victims, of nuclear weaponry.

Finally, then, I suspect that much of the reduced anxiety about nuclear war commonly experienced by both new speakers of the language and long-time experts comes from characteristics of the language itself: the distance afforded by its abstraction; the sense of control afforded by mastering it; and the fact that its content and concerns are that of the users rather than the victims of nuclear weapons. In learning the language, one goes from being the passive, powerless victim to the competent, wily, powerful purveyor of nuclear threats and nuclear explosive power. The enormous destructive effects of nuclear weapons systems become extensions of the self, rather than threats to it.

STAGE 3: DIALOGUE

It did not take very long to learn the language of nuclear war and much of the specialized information it contained. My focus quickly changed from mastering technical information and doctrinal arcana to attempting to understand more about how the dogma was rationalized. Instead of trying, for example, to find out why submarines are so hard to detect or why, prior to the Trident II, submarine-based ballistic missiles were not considered counterforce weapons, I now wanted to know why we really "need" a strategic triad, given submarines' "invulnerability."[40] I also wanted to know why it is considered reasonable to base U.S. military planning on the Soviet Union's military capabilities rather than seriously attempting to gauge what their intentions might be. This standard practice is one I found particularly troubling. Military analysts say that since we cannot know for certain what Soviet intentions are, we must plan our military forces and strategies as if we knew that the Soviets planned to use all of their weapons. While this might appear to have the benefit of prudence, it leads to a major problem. When we ask only what the Soviets can do, we quickly come to assume that that is what they *intend* to do. We base our planning on "worst-case scenarios" and then come to believe that we live in a world where vast resources must be committed to "prevent" them from happening.

Since underlying rationales are rarely discussed in the everyday business of defense planning, I had to start asking more questions. At first, although I was tempted to use my newly acquired proficiency in techno strategic jargon, I vowed to speak English. I had long believed that one of the most important functions of an expert language is exclusion—the denial of a voice to those outside the professional community.[41] I wanted to see whether a well-informed person could speak English and still carry on a knowledgeable conversation.

What I found was that no matter how well-informed or complex my questions were, if I spoke English rather than expert jargon, the men responded to me as though I were ignorant, simpleminded, or both. It did not appear to occur to anyone that I might actually be choosing not to speak their language.

A strong distaste for being patronized and dismissed made my experiment in English short-lived. I adapted my everyday speech to the vocabulary of strategic analysis. I spoke of "escalation dominance," "preemptive strikes," and, one of my favorites, "subholocaust engagements." Using the right phrases opened my way into long, elaborate discussions that taught me a lot about technostrategic reasoning and how to manipulate it.

I found, however, that the better I got at engaging in this discourse, the more impossible it became for me to express my own ideas, my own values. I could adopt the language and gain a wealth of new concepts and reasoning strategies—but at the same time as the language gave me access to things I had been unable to speak about before, it radically excluded others. I could not use the language to express my concerns because it was physically impossible. This language does not allow certain questions to be asked or certain values to be expressed.

To pick a bald example: the word "peace" is not a part of this discourse. As close as one can come is "strategic stability," a term that refers to a balance of numbers and types of weapons systems—not the political, social, economic, and psychological conditions implied by the word "peace." Not only is there no word signifying peace in this discourse, but the word "peace" itself cannot be used. To speak it is immediately to brand oneself as a soft-headed activist instead of an expert, a professional to be taken seriously.

If I was unable to speak my concerns in this language, more disturbing still was that I found it hard even to keep them in my own head. I had begun my research expecting abstract and sanitized discussions of nuclear war and had readied myself to replace my words for theirs, to be ever vigilant against slipping into the never-never land of abstraction. But no matter how prepared I was, no matter how firm my commitment to staying aware of the reality behind the words, over and over I found that I could not stay connected, could not keep human lives as my reference point. I found I could go for days speaking about nuclear weapons without once thinking about the people who would be incinerated by them.

It is tempting to attribute this problem to qualities of the language, the words themselves—the abstractness, the euphemisms, the sanitized, friendly, sexy acronyms. Then all we would need to do is change the words, make them more vivid; get the military planners to say "mass murder" instead of "collateral damage" and their thinking would change.

The problem, however, is not only that defense intellectuals use abstract terminology that removes them from the realities of which they speak. There is no reality of which they speak. Or, rather, the "reality" of which they speak is itself a world of abstractions. Deterrence theory, and much of strategic doctrine altogether, was invented largely by mathematicians, economists, and a few political scientists. It was invented to hold together abstractly, its validity judged by its internal logic. Questions of the correspondence to observable reality were not the issue. These abstract systems were developed as a way to make it possible to "think about the unthinkable"—not as a way to describe or codify relations on the ground.[42]

So the greatest problem with the idea of "limited nuclear war," for example, is not that it is grotesque to refer to the death and suffering caused by *any* use of nuclear weapons as "limited" or that "limited nuclear war" is an abstraction that is disconnected from human reality but, rather, that "limited nuclear war" is itself an abstract conceptual system, designed, embodied, achieved by computer modeling. It is an abstract world in which hypothetical, calm, rational actors have sufficient information to know exactly what size nuclear weapon the opponent has used against which targets, and in which they have adequate command and control to make sure that their response is precisely equilibrated to the attack. In this scenario, no field commander would use the tactical "mini-nukes" at his disposal in the height of a losing battle; no EMP-generated electronic failures, or direct attacks on command.. and control centers, or human errors would destroy communications networks. Our rational actors would be free of emotional response to being attacked, free of political pressures from the populace, free from madness or despair or any of the myriad other factors that regularly affect human actions and decision making. They would act solely on the basis of a perfectly informed mathematical calculus of megatonnage.

So to refer to "limited nuclear war" is already to enter into a system that is de facto abstract and removed from reality. To use more descriptive language would not, by itself, change that. In fact, I am tempted to say that the abstractness of the entire conceptual system makes descriptive language nearly beside the point. In a discussion of "limited nuclear war," for example, it might make some difference if in place of saying "In a counter force attack against hard targets collateral damage could be limited," a strategic analyst had to use words that were less abstract—if he had to say, for instance, "If we launch the missiles we have aimed at their missile silos, the explosions would cause the immediate mass murder of 10 million women, men, and children, as well as the extended illness, suffering, and eventual death of many millions more." It is true that the second sentence does not roll off the tongue or slide across one's consciousness quite as easily. But it is also true, I believe, that the ability to speak about "limited nuclear war" stems as much, if not more, from the fact that the term "limited nuclear war" refers to an abstract conceptual system rather than to events that might take place in the real world. As such, there is no need to think about the concrete human realities behind the model; what counts is the internal logic of the system.[43]

This realization that the abstraction was not just in the words but also characterized the entire conceptual system itself helped me make sense of my difficulty in staying connected to human lives. But there was still a piece missing. How is it possible, for example, to make sense of the following paragraph? It is taken from a discussion of a scenario ("regime A") in which the United States and the USSR have revised their offensive weaponry, banned MIRVs, and gone to a regime of single warhead (Midgetman) missiles, with no "defensive shield" (or what is familiarly known as "Star Wars" or SDI):

> The strategic stability of regime A is based on the fact that both sides are deprived of any incentive ever to strike first. Since it takes roughly two warheads to destroy one enemy silo, an attacker must expend two of his missiles to destroy one of the enemy's. A first strike disarms the attacker. The aggressor ends up worse off than the aggressed.[44]

"The aggressor ends up worse off than the aggressed"? The homeland of "the aggressed" has just been devastated by the explosions of, say, a thousand nuclear bombs, each likely to be ten to one hundred times more powerful than the bomb dropped on Hiroshima, and the aggressor, whose homeland is still untouched, "ends up worse off"? How is it possible to think this? Even abstract language and abstract thinking do not seem to be a sufficient explanation.

I was only able to "make sense of it" when I finally asked myself the question that feminists have been asking about theories in every discipline: What is the reference point? Who (or what) is the *subject* here?

In other disciplines, we have frequently found that the reference point for theories about "universal human phenomena" has actually been white men. In technostrategic discourse, the reference point is not white men, it is not human beings at all; it is the weapons themselves. The aggressor thus ends up worse off than the aggressed because he has fewer weapons left; human factors are irrelevant to the calculus of gain and loss.

In "regime A" and throughout strategic discourse, the concept of "incentive" is similarly distorted by the fact that weapons are the subjects of strategic paradigms. Incentive to strike first is present or absent according to a mathematical calculus of numbers of "surviving" weapons. That is, incentive to start a nuclear war is discussed not in terms of what possible military or political ends it might serve but, instead, in terms of numbers of weapons, with the goal being to make sure that you are the guy who still has the most left at the end. Hence, it is frequently stated that MIRVed missiles create strategic instability because they "give you the incentive to strike first." Calculating that two warheads must be targeted on each enemy missile, one MIRVed missile with ten warheads would, in theory, be able to destroy five enemy missiles in their silos; you destroy more of theirs than you have expended of your own. You win the numbers game. In addition, if you do not strike first, it would theoretically take relatively few of their MIRVed missiles to destroy a larger number of your own—so you must, as they say in the business, "use 'em or lose 'em." Many strategic analysts fear that in a period of escalating political tensions, when it begins to look as though war may be inevitable, this combination makes "the incentive to strike first" well nigh irresistible.

Incentive to launch a nuclear war arises from a particular configuration of weapons and their hypothetical mathematical interaction. Incentive can only be so narrowly defined because the referents of technostrategic paradigms are weapons—not human lives, not even states and state power.

The fact that the subjects of strategic paradigms are weapons has several important implications. First, and perhaps most critically, there simply is no way to talk about human death or human societies when you are using a language designed to talk about weapons. Human death simply is "collateral damage"—collateral to the real subject, which is the weapons themselves.

Second, if human lives are not the reference point, then it is not only impossible to talk about humans in this language, it also becomes in some sense illegitimate to ask the paradigm to reflect human concerns. Hence, questions that break through the numbing language of strategic analysis and raise issues in human terms can be dismissed easily. No one will claim that the questions are unimportant, but they are inexpert, unprofessional, irrelevant to the business at hand to ask. The discourse among the experts remains hermetically sealed.

The problem, then, is not only that the language is narrow but also that it is seen by its speakers as complete or whole unto itself—as representing a body of truths that exist independently of any other truth or knowledge. The isolation of this technical knowledge from social or psychological or moral thought, or feelings, is all seen as legitimate and necessary. The outcome is that defense intellectuals can talk about the weapons that are supposed to protect particular political entities, particular peoples and their way of life, without actually asking if weapons can do it, or if they are the best *way* to do it, or whether they may even damage the entities you are supposedly protecting. It is not that the men I spoke with would say that these are invalid questions. They would, however, simply say that they are separate questions, questions that are outside what they do, outside their realm of expertise. So their deliberations go on quite independently, as though with a life of their own, disconnected from the functions and values they are supposedly to serve.

Finally, the third problem is that this discourse has become virtually the only legitimate form of response to the question of how to achieve security. If the language of weaponry was one competing voice in the discussion, or one that was integrated with others, the fact that the referents of strategic paradigms are only weapons would be of little note. But when we realize that the only language and expertise offered to those interested in pursuing peace refers to nothing but weapons, its limits become staggering, and its entrapping qualities—the way in which, once you adopt it, it becomes so hard to stay connected to human concerns become more comprehensible.

STAGE 4: THE TERROR

As a newcomer to the world of defense analysts, I was continually startled by likeable and admirable men, by their gallows humor, by the bloodcurdling casualness with which they regularly blew up the world while standing and chatting over the coffee pot. I also *heard* the language they spoke heard the acronyms and euphemisms, and abstractions, heard the imagery, heard the pleasure with which they used it.

Within a few weeks, what had once been remarkable became unnoticeable. As I learned to speak, my perspective changed. I no longer stood outside the impermeable wall of technostrategic language and, once inside, I could no longer see it. Speaking the language, I could no longer really hear it. And once inside its protective walls, I began to find it difficult to get out. The impermeability worked both ways.

I had not only learned to speak a language: I had started to think in it. Its questions became my questions, its concepts shaped my responses to new ideas. Its definitions of the parameters of reality became mine. Like the White Queen, I began to believe six impossible things before breakfast. Not because I consciously believed, for instance, that a "surgically clean counterforce strike" was really possible, but instead because some elaborate piece of doctrinal reasoning I used was already predicated on the possibility of those strikes, as well as on a host of other impossible things.[45]

My grasp on what I knew as reality seemed to slip. I might get very excited, for example, about a new strategic justification for a "no first use" policy and spend time discussing the ways in which its implications for our force structure in Western Europe were superior to the older version.[46]

And after a day or two I would suddenly step back, aghast that I was so involved with the military justifications for not using nuclear weapons—as though the moral ones were not enough. What I was actually talking about—the mass incineration caused by a nuclear attack—was no longer in my head.

Or I might hear some proposals that seemed to me infinitely superior to the usual arms control fare. First I would work out how and why these proposals were better and then work out all the ways to counter the arguments against them. But then, it might dawn on me that even though these two proposals sounded so different, they still shared a host of assumptions that I was not willing to make (e.g., about the inevitable, eternal conflict of interests between the United States and the USSR, or the desirability of having some form of nuclear deterrent, or the goal of "managing," rather than ending, the nuclear arms race). After struggling to this point of seeing what united both positions, I would first feel as though I had really accomplished something. And then all of a sudden, I would realize that these new insights were things I actually knew *before I ever entered* this community. Apparently, I had since forgotten them, at least functionally, if not absolutely.

I began to feel that I had fallen down the rabbit hole—and it was a struggle to climb back out.

CONCLUSIONS

Suffice it to say that the issues about language do not disappear after you have mastered technostrategic discourse. The seductions remain great. You can find all sorts of ways to seemingly beat the boys at their own game; you can show how even within their own definitions of rationality, most of what is happening in the development and deployment of nuclear forces is wildly irrational. You can also impress your friends and colleagues with sickly humorous stories about the way things really happen on the inside. There is tremendous pleasure in it, especially for those of us who have been closed out, who have been told that it is really all beyond us and we should just leave it to the benevolently paternal men in charge.

But as the pleasures deepen, so do the dangers. The activity of trying to out-reason defense intellectuals in their own games gets you thinking inside their rules, tacitly accepting all the unspoken assumptions of their paradigms. You become subject to the tyranny of concepts. The language shapes your categories of thought (e.g., here it becomes "good nukes" or "bad nukes," not, nukes or no nukes) and defines the boundaries of imagination (as you try to imagine a "minimally destabilizing basing mode" rather than a way to prevent the weapon from being deployed at all).

Yet, the issues of language have now become somewhat less vivid and central to me. Some of the questions raised by the experiences described here remain important, but others have faded and been superseded by new questions. These, while still not precisely the questions of an "insider," are questions I could not have had without being inside, without having access to the knowledge and perspective the inside position affords. Many of my questions now are more practical—which individuals and institutions are actually responsible for the endless "modernization" and proliferation of nuclear weaponry? What role does technostrategic rationality actually play in their thinking? What would a reasonable, genuinely defensive "defense" policy look like? Others are more philosophical. What is the nature of the rationality and "realism" claimed by defense intellectuals for their mode of thinking? What are the many different grounds on which their claims to rationality can be shown to be spurious?

My own move away from a focus on the language is quite typical. Other recent entrants into this world have commented to me that, while it is the cold-blooded, abstract discussions that are most striking at first, within a short time "you get past it—you stop hearing it, it stops bothering you, it becomes normal—and you come to see that the language, itself, is not the problem."

However, I think it would be a mistake to dismiss these early impressions. They can help us learn something about the militarization of the mind, and they have, I believe, important implications for feminist scholars and activists who seek to create a more just and peaceful world.

Mechanisms of the mind's militarization are revealed through both listening to the language and learning to speak it. *Listening*, it becomes clear that participation in the world of nuclear strategic analysis does not necessarily require confrontation with the central fact about military activity—that the purpose of all weaponry and all strategy is to injure human bodies.[47] In fact, as Elaine Scarry points out, participation in military thinking does not require confrontation with, and actually demands the elision of, this reality.[48]

Listening to the discourse of nuclear experts reveals a series of culturally grounded and culturally acceptable mechanisms that serve this purpose and that make it possible to "think about the unthinkable," to work in institutions that foster the proliferation of nuclear weapons, to plan mass incinerations of millions of human beings for a living. Language that is abstract, sanitized, full of euphemisms; language that is sexy and fun to use; paradigms whose referent is weapons; imagery that domesticates and deflates the forces of mass destruction; imagery that reverses sentient and nonsentient matter, that conflates birth and death, destruction and creation—all of these are part of what makes it possible to be radically removed from the reality of what one is talking about and from the realities one is creating through the discourse.[49]

Learning to speak the language reveals something about how thinking can become more abstract, more focused on parts disembedded from their context, more attentive to the survival of weapons than the survival of human beings. That is, it reveals something about the process of militarization—and the way in which that process may be undergone by man or woman, hawk or dove.

Most often, the act of learning technostrategic language is conceived of as an additive process: you add a new set of vocabulary words; you add the reflex ability to decode and use endless numbers of acronyms; you add some new information that the specialized language contains; you add the conceptual tools that will allow you to "think strategically." This additive view appears to be held by defense intellectuals themselves; as one said to me, "Much of the debate is in technical terms—learn it, and decide whether it's relevant later." This view also appears to be held by many who think of themselves as antinuclear, be they scholars and professionals attempting to change the field from within, or public interest lobbyists and educational organizations, or some feminist antimilitarists.[50] Some believe that our nuclear policies are so riddled with irrationality that there is a lot of room for well-reasoned, well-informed arguments to make a difference; others, even if they do not believe that the technical information is very important, see it as necessary to master the language simply because it is too difficult to attain public legitimacy without it. In either case, the idea is that you add the expert language and information and proceed from there.

However, I have been arguing throughout this paper that learning the language is a transformative, rather than an additive, process. When you choose to learn it you enter a new mode of thinking—a mode of thinking not only about nuclear weapons but also, de facto, about military and political power and about the relationship between human ends and technological means.

Thus, those of us who find U.S. nuclear policy desperately misguided appear to face a serious quandary. If we refuse to learn the language, we are virtually guaranteed that our voices will remain outside the "politically relevant" spectrum of opinion. Yet, if we do learn and speak it, we not only severely limit what we can say but we also invite the transformation, the militarization, of our own thinking.

I have no solutions to this dilemma, but I would like to offer a few thoughts in an effort to reformulate its terms. First, it is important to recognize an assumption implicit in adopting the strategy of learning the language. When we assume that learning and speaking the language will give us a voice recognized as legitimate and will give us greater political influence, *we are assuming that the language itself actually articulates the criteria and reasoning strategies upon which nuclear weapons development and deployment decisions are made.* I believe that this is largely an illusion. Instead, I want to suggest that technostrategic discourse functions more as a gloss, as an ideological curtain behind which the actual reasons for these decisions hide. That rather than informing and shaping decisions, it far more often functions as a legitimation for political outcomes that have occurred for utterly different reasons. If this is true, it raises some serious questions about the extent of the political returns we might get from using technostrategic discourse, and whether they can ever balance out the potential problems and inherent costs.

I do not, however, want to suggest that none of us should learn the language. I do not believe that this language is well suited to achieving the goals desired by antimilitarists, yet at the same time, I, for one, have found the experience of learning the language useful and worthwhile (even if at times traumatic). The question for those of us who do choose to learn it, I think, is what use are we going to make of that knowledge?

One of the most intriguing options opened by learning the language is that it suggests a basis upon which to challenge the legitimacy of the defense intellectuals' dominance of the discourse on nuclear issues. When defense intellectuals are criticized for the cold-blooded inhumanity of the scenarios they plan, their response is to claim the high ground of rationality; they are the only ones whose response to the existence of nuclear weapons is objective and realistic. They portray those who are radically opposed to the nuclear status quo as irrational, unrealistic, too emotional. "Idealistic activists" is the pejorative they set against their own hard-nosed professionalism.

Much of their claim to legitimacy, then, is a claim to objectivity born of technical expertise and to the disciplined purging of the emotional valences that might threaten their objectivity. But if the surface of their discourse its abstraction and technical jargon appears at first to support these claims, a look just below the surface does not. There we find currents of homoerotic excitement, heterosexual domination, the drive toward competency and mastery, the pleasures of membership in an elite and privileged group, the ultimate importance and meaning of membership in the priesthood, and the thrilling power of becoming Death, shatterer of worlds. How is it possible to hold this up as a paragon of coolheaded objectivity?

I do not wish here to discuss or judge the holding of "objectivity" as an epistemological goal. I would simply point out that, as defense intellectuals rest their claims to legitimacy on the untainted rationality of their dis course, their project fails according to its own criteria. Deconstructing strategic discourse's claims to rationality is, then, in and of itself, an important way to challenge its hegemony as the sole legitimate language for public debate about nuclear policy.

I believe that feminists, and others who seek a more just and peaceful world, have a dual task before us—a deconstructive project and a reconstructive project that are intimately linked.[51] Our deconstructive task requires close attention to, and the dismantling of, technostrategic dis course. The dominant voice of militarized masculinity and decontextualized rationality speaks so loudly in our culture, it will remain difficult for any other voices to be heard until that voice loses some of its power to define what we hear and how we name the world—until that voice is delegitimated.

Our reconstructive task is a task of creating compelling alternative visions of possible futures, a task of recognizing and developing alternative conceptions of rationality, a task of creating rich and imaginative alternative voices—diverse voices whose conversations with each other will invent those futures.

NOTES

1. Thomas Powers, "How Nuclear War Could Start," *New York Review of Books* (January 17, 1985), 33.
2. George Kennan, "A Modest Proposal," *New York Review of Books* (July 16, 1981), 14.
3. It is unusual for defense intellectuals to write for the public, rather than for their colleagues, but a recent, interesting exception has been made by a group of defense analysts from Harvard. Their two books provide a clear expression of the stance that living with nuclear weapons is not so much a problem to be solved but a condition to be managed rationally. Albert Camesale and the Harvard Nuclear Study Group, *Living with Nuclear Weapons* (Cambridge, Mass.: Harvard University Press, 1984); and Graham T. Allison, Albert Carne sale, and Joseph Nye, Jr., eds., *Hawks, Doves, and Owls: An Agenda for Avoiding Nuclear War* (New York: W.W. Norton & Co., 1985).
4. For useful introductions to feminist work on gender and language, see Barrie Thome, Cheris Kramarae, and Nancy Henley, eds., *Language, Gender and Society* (Rowley, Mass.: Newbury Publishing House, 1983); and Elizabeth Abel, ed., *Writing and Sexual Difference* (Chicago: University of Chicago Press, 1982).
5. For feminist critiques of dominant Western conceptions of rationality, see Nancy Hartsock, *Money, Sex, and Power* (New York: Longman, 1983); Sandra Harding and Merrill Hintikka, eds., *Discovering Reality: Feminist Perspectives on Epistemology, Metaphysics, Methodology and the Philosophy of Science* (Dordrecht: D. Reidel Publishing Co., 1983); Evelyn Fox Keller, *Reflections on Gender and Science* (New Haven, Conn.: Yale University Press, 1985); Jean Bethke Elshtain, *Public Man, Private Woman: Woman in Social and Political Thought* (Princeton, N.J.: Princeton University Press, 1981); Genevieve Lloyd, *The Man of Reason: "Male" and "Femole" in Western Philosophy* (Minneapolis: University of Minnesota Press, 1984), which contains a particularly useful bibliographic essay; Sara Ruddick, "Remarks on the Sexual Politics of Reason," in *Women and Moral Theory*, ed. Eva Kittay and Diana Meyers (Totowa, N.J.: Rowman & Allanheld, in press). Some of the growing feminist work on gender and war is explicitly connected to critiques of rationality. See Virginia Woolf, *Three Guineas* (New York: Harcourt, Brace, Jovanovich, 1966); Nancy

C. M. Hartsock, "The Feminist Standpoint: Developing the Grounds for a Specifically Feminist Historical Materialism," in Harding and Hintikka, eds., 283–310, and "The Barracks Community in Western Political Thought: Prologomena to a Feminist Critique of War and Politics," in *Women and Men's Wars*, ed. Judith Hicks Stiehm (Oxford: Pergamon Press, 1983); Jean Bethke Elshtain, "Reflections on War and Political Discourse: Realism, Just War and Feminism in a Nuclear Age," *Political Theory* 13, no. 1 (February 1985): 39–57; Sara Ruddick, "Preservative Love and Military Destruction: Some Reflections on Mothering and Peace," in *Mothering: Essays in Feminist Theory*, ed. Joyce Trebilcot (Totowa, N.J.: Rowman & Allanheld, 1984), 231–62; Genevieve Lloyd, "Selfhood, War, and Masculinity," in *Feminist Challenges*, ed. E. Gross and C. Pateman (Boston: Northeastern University Press, 1986). There is a vast and valuable literature on gender and war that indirectly informs my work. See, e.g., Cynthia Enloe, *Does Khaki Become You? The Militarization of Women's Lives* (Boston: South End Press, 1984); Stiehm, ed.; Jean Bethke Elshtain, "On Beautiful Souls, Just Warriors, and Feminist Consciousness," in Stiehm, ed., 341–48; Sara Ruddick, "Pacifying the Forces: Drafting Women in the Interests of Peace," *Signs: Journal of Women in Culture and Society* 8, no. 3 (Spring 1983): 471–89, and "Drafting Women: Pieces of a Puzzle," in *Conscripts and Volunteers: Military Requirements, Social Values, and the ALL-Volunteer Force*, ed. Robert K. Fullinwider (Totowa, N.J.: Rowman & Allanheld, 1983); Amy Swerdlow, "Women's Strike for Peace versus HUAC," *Feminist Studies* 8, no. 3 (Fall 1982): 493–5; Mary C. Segers, "The Catholic Bishops' Pastoral Letter on War and Peace: A Feminist Perspective," *Feminist Studies* 11, no. 3 (Fall 1985): 619–47.

6. I have coined the term "technostrategic" to represent the intertwined, inextricable nature of technological and nuclear strategic thinking. The first reason is that strategic thinking seems to change in direct response to technological changes, rather than political thinking, or some independent paradigms that might be isolated as "strategic." (On this point, see Lord Solly Zuckerman, *Nuclear Illusions and Reality* [New York: Viking Press, 1982]). Even more important, strategic theory not only depends on and changes in response to technological objects, it is also based on a kind of thinking, a way of looking at problems—formal, mathematical modeling, systems analysis, game theory, linear programming—that are part of technology itself. So I use the term "technostrategic" to indicate the degree to which nuclear strategic language and thinking are imbued with, indeed constructed out of, modes of thinking that are associated with technology.
7. Fusion weapons' proportionally smaller yield of radioactive fallout led Atomic Energy Commission Chairman Lewis Strauss to announce in 1956 that hydrogen bomb tests were important "not only from a military point of view but from a humanitarian aspect." Although the bombs being tested were 1,000 times more powerful than those that devastated Hiroshima and Nagasaki, the proportional reduction of fallout apparently qualified them as not only clean but also humanitarian. Lewis Strauss is quoted in Ralph Lapp, "The 'Humanitarian' H-Bomb," *Bulletin of Atomic Scientists* 12, no. 7 (September 1956): 263.
8. I must point out that we cannot know whether to take this particular example literally: America's list of nuclear targets is, of course, classified. The defense analyst quoted, however, is a man who has had access to that list for at least two decades. He is also a man whose thinking and speaking is careful and precise, so I think it is reasonable to assume that his statement is not a distortion, that "shoe factories," even if not themselves literally targeted, accurately represent a category of target. Shoe factories would be one among many "military targets" other than weapons systems themselves; they would be military targets because an army needs boots. The likelihood of a nuclear war lasting long enough for foot soldiers to wear out their boots might seem to stretch the limits of credibility, but that is an insufficient reason to assume that they are not nuclear targets. Nuclear targeting and nuclear strategic planning in general frequently suffer from "conventionalization"—the tendency of planners to think in the old, familiar terms of "conventional" warfare rather than fully assimilating the ways in which nuclear weaponry has changed warfare. In avoiding talking about murder, the defense community has long been ahead of the State Department. It was not until1984 that the State Department announced it will no longer use the word "killing," much less "murder," in official reports on the status of human rights in allied countries. The new term is "unlawful or arbitrary deprivation of life" (*New York Times*, February 15, 1984, as cited in *Quarterly Review of Doublespeak* 11, no. 1 [October 1984]: 3).
9. "Kiloton" (or kt) is a measure of explosive power, measured by the number of thousands of tons of TNT required to release an equivalent amount of energy. The atomic bomb dropped on Hiroshima is estimated to have been approximately 12 kt. An MX missile is designed to carry up to ten Mk 21

reentry vehicles, each with a W-87 warhead. The yield of W-87 warheads is 300 kt, but they are "upgradable" to 475 kt.

10. Since the MX would theoretically be able to "take out" Soviet land-based ICBMs in a "disarming first strike," the Soviets would have few ICBMs left for a retaliatory attack, and thus damage to the United States theoretically would be limited. However, to consider the damage that could be inflicted on the United States by the remaining ICBMs, not to mention Soviet bombers and submarine-based missiles as "limited" is to act as though words have no meaning.
11. Conservative government assessments of the number of deaths resulting from a "surgically clean" counterforce attack vary widely. The Office of Technology Assessment projects 2 million to 20 million immediate deaths. (See James Fallows, *National Defense* [New York: Random House, 1981], 159.) A 1975 Defense Department study estimated 18.3 million fatalities, while the U.S. Arms Control and Disarmament Agency, using different assumptions, arrived at a figure of 50 million (cited by Desmond Ball, "Can Nuclear War Be Controlled?" Adelphi Paper no. 169 [London: International Institute for Strategic Studies, 1981]).
12. The phrase is Helen Caldicott's in *Missile Envy: The Arms Race and Nuclear War* (Toronto: Bantam Books, 1986).
13. For the uninitiated, "penetration aids" refers to devices that help bombers or missiles get past the "enemy's" defensive systems; e.g., stealth technology, chaff, or decoys. Within the defense intellectual community, they are also familiarly known as "penaids."
14. General William Odom, "C31and Telecommunications at the Policy Level," Incidental Paper, Seminar on C31: Command, Control, Communications and Intelligence (Cambridge, Mass.: Harvard University, Center for Information Policy Research, Spring 1980).
15. '"This point has been amply documented by Brian Easlea, *Fathering the Unthinkable: Masculinity, Scientists and the Nuclear Arms Race* (London: Pluto Press, 1983).
16. *Air Force Magazine* 68, no. 6 (June 1985): 77–78.
17. Ibid.
18. William L. Laurence, *Dawn over Zero: The Study of the Atomic Bomb* (London: Museum Press, 1974), 19.
19. U.S.A.F. Retired General T.R. Milton, "Nuclear Virginity," *Air Force Magazine* 68, no. 5 (May 1985): 44.
20. I am grateful to Margaret Cerullo, a participant in the first summer program, for reporting the use of this analogy to me and sharing her thoughts about this and other events in the program. The interpretation I give here draws strongly on hers.
21. MIRV stands for "multiple independently targetable re-entry vehicles." A MIRVed missile not only carries more than one warhead; its warheads can be aimed at different targets.
22. Henry T. Nash, "The Bureaucratization of Homicide," *Bulletin of Atomic Scientists* (April1980), reprinted in E. P. Thompson and Dan Smith, eds., *Protest and Survive* (New York: Monthly Review Press, 1981), 159. The neutron bomb is notable for the active political contention that has occurred over its use and naming. It is a small warhead that produces six times the prompt radiation but slightly less blast and heat than typical fission warheads of the same yield. Pentagon planners see neutron bombs as useful in killing Soviet tank crews while theoretically leaving the buildings near the tanks intact. Of course, the civilians in the nearby buildings, however, would be killed by the same "enhanced radiation" as the tank crews. It is this design for protecting property while killing civilians along with soldiers that has led people in the antinuclear movement to call the neutron bomb "the ultimate capitalist weapon." However, in official parlance the neutron bomb is not called a weapon at all; it is an "enhanced radiation device." It is worth noting, however, that the designer of the neutron bomb did not conceive of it as an anti-tank personnel weapon to be used against the Russians. Instead, he thought it would be useful in an area where the enemy did not have nuclear weapons to use. (Samuel T. Cohen, in an interview on National Public Radio, as reported in Fred Kaplan, "The Neutron Bomb: What It Is, the Way It Works," *Bulletin of Atomic Scientists* [October 1981], 6.)
23. For a discussion of the functions of imagery that reverses sentient and insentient matter, that "exchange[s] . . . idioms between weapons and bodies," see Elaine Scarry, *The Body in Pain: The Making and Unmaking of the World* (New York: Oxford University Press, 1985), 60–157, esp. 67.
24. For further discussion of men's desire to appropriate from women the power of giving life and death, and its implications for men's war-making activities, see Dorothy Dinnerstein, *The Mermaid and the Minotaur* (New York: Harper & Row, 1977). For further analysis of male birth imagery in the atomic bomb project, see Evelyn Fox Keller, "From Secrets of Life to Secrets of Death" (paper delivered at the Kansas Seminar, Yale University, New Haven, Conn., November 1986); and Easlea (n. 15 above), 81–116.

25. Lawrence is quoted by Herbert Childs in *An American Genius: The Life of Ernest Orlando Lawrence* (New York: E. P. Dutton, 1968), 340.
26. Feynman writes about the telegram in Richard P. Feynman, "Los Alamos from Below," in *Reminiscences of Los Alamos, 1943–1945*, ed. Lawrence Badash, Joseph O. Hirshfelder, and Herbert P. Broida (Dordrecht: D. Reidel Publishing Co., 1980), 130.
27. Hans Bethe is quoted as saying that "Ulam was the father of the hydrogen bomb and Edward was the mother, because he carried the baby for quite a while" (J. Bernstein, *Hans Bethe: Prophet of Energy* [New York: Basic Books, 1980], 95).
28. The MILSTAR system is a communications satellite system that is jam resistant, as well as having an "EMP-hardened capability." (This means that the electromagnetic pulse set off by a nuclear explosion would theoretically not destroy the satellites' electronic systems.) There are, of course, many things to say about the sanity and morality of the idea of the MILSTAR system and of spending the millions of dollars necessary to EMP-harden it. The most obvious point is that this is a system designed to enable the United States to fight a "protracted" nuclear war—the EMP-hardening is to allow it to act as a conduit for command and control of successive nuclear shots, long after the initial exchange. The practicality of the idea would also appear to merit some discussion—who and what is going to be communicating to and from after the initial exchange? And why bother to harden it against EMP when all an opponent has to do to prevent the system from functioning is to blow it up, a feat certain to become technologically feasible in a short time? But, needless to say, exploration of these questions was not part of the briefing.
29. The concern about having a boy, not a girl, is written about by Robert Jungk, *Brighter Than a Thousand Suns*, trans. James Cleugh (New York: Harcourt, Brace & Co., 1956), 197.
30. Richard E. Hewlett and Oscar E. Anderson, *The New World, 1939146: A History of the United States Atomic Energy Commission*, 2 vols. (University Park: Pennsylvania State University Press, 1962), 1:386.
31. Winston Churchill, *The Second World War*, vol. 6., *Triumph and Tragedy* (London: Cassell, 1954), 551.
32. Quoted by Easlea, 130.
33. Laurence (n. 18 above), 10.
34. Ibid., 188.
35. From a 1985 interview in which Holloway was explaining the logic of a "decapitating" strike against the Soviet leadership and command and control systems—and thus how nuclear war would be different from World War II, which was a "war of attrition," in which transportation, supply depots, and other targets were hit, rather than being a "big bang" (Daniel Ford, "The Button," *New Yorker Magazine* 61, no. 7 [April 8, 1985], 49).
36. Jungk, 201.
37. Hisako Matsubara, *Cranes at Dusk* (Garden City, N.Y.: Dial Press, 1985). The author was a child in Kyoto at the time the atomic bomb was dropped. Her description is based on the memories of survivors.
38. General Robert Rosenberg (formerly on the National Security Council staff during the Carter Administration), "The Influence of Policymaking on C31," Incidental Paper, Seminar on C31 (Cambridge, Mass.: Harvard University, Center for Information Policy Research, Spring 1980), 59.
39. Two other writers who have remarked on this division of languages between the "victims" and the professionals (variously named) are Freeman Dyson and Glenn D. Hook. Dyson, in *Weapons and Hope* (New York: Harper & Row, 1984), notes that there are two languages in the current discussion of nuclear weapons, which he calls the language of "the victims" and the language of "the warriors." He sees the resulting problem as being the difficulty the two groups have in communicating with each other and, thus, in appreciating each other's valid concerns. His project, then, is the search for a common language, and a good portion of the rest of the book is directed toward that end. Hook, in "Making Nuclear Weapons Easier to Live With: The Political Role of Language in Nuclearization," *Journal of Peace Research* 22, no. 1(1985): 67–77, follows Camus in naming the two groups "the victims" and "the executioners." He is more explicit than Dyson about naming these as perspectives, as coming from positions of greater or lesser power, and points out that those with the most power are able to dominate and define the terms in which we speak about nuclear issues, so that no matter who we are, we find ourselves speaking as though we were the users, rather than the victims of nuclear weapons. Although my analysis of perspectives and the ways in which language inscribes relations of power is similar to his, I differ from Hook in finding in this fact one of the sources of the experts' relative lack of fear of nuclear war.
40. The "strategic triad" refers to the three different modes of basing nuclear warheads: at land, on intercontinental ballistic missiles; at sea, on missiles in submarines; and "in the air," on the Strategic Air Command's bombers. Given that nuclear weapons based on submarines are

"invulnerable" (i.e., not subject to attack), since there is not now nor likely to be in the future any reliable way to find and target submarines, many commentators (mostly from outside the community of defense intellectuals) have suggested that the Navy's leg of the triad is all we need to ensure a capacity to retaliate against a nuclear attack. This suggestion that submarine-based missiles are an adequate deterrent becomes especially appealing when it is remembered that the other basing modes—ICBMs and bombers—act as targets that would draw thousands of nuclear attacks to the American mainland in time of war.

41. For an interesting recent discussion of the role of language in the creation of professional power, see JoAnne Brown, "Professional Language: Words That Succeed," *Radical History Review,* no. 34 (1986), 33–51.
42. For fascinating, detailed accounts of the development of strategic doctrine, see Fred Kaplan, *The Wizards of Armageddon* (New York: Simon &: Schuster, 1983); and Gregg F. Herken, *The Counsels of War* (New York: Alfred A. Knopf, 1985).
43. Steven Kull's interviews with nuclear strategists can be read to show that on some level, some of the time, some of these men are aware that there is a serious disjunction between their models and the real world. Their justification for continuing to use these models is that "other people" (unnamed, and on asking, unnameable) believe in them and that they therefore have an important reality ("Nuclear Nonsense," *Foreign Policy*, no. 58 [Spring 1985), 28–52).
44. Charles Krauthammer, "Will Star Wars Kill Arms Control?" *New Republic*, no. 3,653 (January 21, 1985), 12–16.
45. For an excellent discussion of the myriad uncertainties that make it ludicrous to assume the targeting accuracies posited in the notion of "surgically clean counterforce strikes," see Fallows (n. 11 above), chap. 6.
46. "No first use" refers to the commitment not to be the first side to introduce nuclear weapons into a "conventional" war. The Soviet Union has a "no first use" policy, but the United States does not. In fact, it is NATO doctrine to use nuclear weapons in a conventional war in Western Europe, as a way of overcoming the Warsaw Pact's supposed superiority in conventional weaponry and troop strength.
47. For an eloquent and graphic exploration of this point, see Scarry (n. 23 above), 73.
48. Scarry catalogs a variety of mechanisms that serve this purpose (ibid., 60–157). The point is further developed by Sara Ruddick, "The Rationality of Care," in *Thinking about Women, War, and the Military*, ed. Jean Bethke Elshtain and Sheila Tobias (Totowa, N.J.: Rowman & Allanheld, in press).
49. My discussion of the specific ways in which this discourse creates new realities is in the next part of this project, entitled, "The Emperor's New Armor." I, like many other social scientists, have been influenced by poststructuralist literary theory's discussion of deconstructing texts, point of view, and narrative authority within texts, and I take the language and social practice of the defense intellectuals as a text to be read in this way. For a classic introduction to this literature, see Josue Harari, ed., *Textual Strategies: Perspectives in Post-structuralist Criticism* (Ithaca, N.Y.: Cornell University Press, 1979); and Jacques Derrida, *Of Grammatology* (Baltimore: Johns Hopkins University Press, 1976).
50. Perhaps the most prominent proponent of this strategy is Sheila Tobias. See, e.g., "Demystifying Defense: Closing the Knowledge Gap," *Social Policy* 13, no. 3 (1983): 29–32; and Sheila Tobias, Peter Goudinoff, Stefan Leader, and Shelah Leader, *What Kinds of Guns Are They Buying for Your Butter?* (New York: William Morrow & Co., 1982).
51. Harding and Hintikka, eds. (n. 5 above), ix–xix, esp. x.

CHAPTER 10

Socially Camouflaged Technologies: The Case of the Electromechanical Vibrator

Rachel Maines

Certain commodities are sold in the legal marketplace for which the expected use is either illegal or socially unacceptable. Marketing of these goods, therefore, requires camouflaging of the design purpose in a verbal and visual rhetoric that conveys to the knowledgeable consumer the item's selling points without actually endorsing its socially prohibited uses. I refer not to goods that are actually illegal in character, such as marijuana, but to their grey-market background technologies, such as cigarette rolling papers. Marketing efforts for goods of this type have similar characteristics over time, despite the dissimilarity of the advertised commodities. I shall discuss here an electromechanical technology that addresses formerly prohibited expressions of women's sexuality-the vibrator in its earliest incarnation between 1870 and 1930. Comparisons will be drawn between marketing strategies for this electromechanical technology, introduced between 1880 and 1903, and that of emmenagogues, distilling, burglary tools, and computer software copying, as well as the paradigm example of drug paraphernalia.

I shall argue here that electromechanical massage of the female genitalia achieved acceptance during the period in question by both professionals and consumers not only because it was less cumbersome, labor-intensive and costly than predecessor technologies, but because it maintained the social camouflage of sexual massage treatment through its associations with modern professional instrumentation and with prevailing beliefs about electricity as a healing agent.[1]

The case of the electromechanical vibrator, as a technology associated with women's sexuality, involves issues of acceptability rather than legality. The vibrator and its predecessor technologies, including the dildo, are associated with masturbation, a socially prohibited activity until well into the second half of this century.[2] Devices for mechanically-assisted female masturbation, mainly vibrators and dildoes, were marketed in the popular press from the late nineteenth century through the early thirties in similarly camouflaged advertising. Such advertisements temporarily disappeared from popular literature after the vibrator began to appear in stag films, which may have rendered the camouflage inadequate, and did not resurface until social change made it unnecessary to disguise the sexual uses of the device.[3]

For purposes of this discussion, a vibrator is a mechanical or electromechanical appliance imparting rapid and rhythmic pressure through a contoured working surface usually mounted at a right angle to the handle. These points of contact generally take the form of a set of interchangeable vibratodes configured to the anatomical areas they are intended to address. Vibrators are rarely employed internally in masturbation; they thus differ from dildoes, which are generally straight-shafted and may or may not include a vibratory component. Vibrators are here distinguished also from massagers, the working surfaces of which are flat or dished.[4] It should be noted that this is a historian's distinction imposed on the primary sources; medical authors and appliance manufacturers apply a heterogeneous nomenclature to massage technologies. Vibrators and dildoes rarely appeared in household advertising between 1930 and 1955, massagers continued to be marketed, mainly through household magazines.[5]

The electromechanical vibrator, introduced as a medical instrument in the 1880s and as a home appliance between 1900 and 1903, represented the convergence of several older medical massage technologies, including manual, hydriatic, electro therapeutic and mechanical methods. Internal and external gynecological massage with lubricated fingers had been a standard medical treatment for hysteria, disorders of menstruation and other female complaints at least since the time of Aretaeus Cappadox (circa 150 A.D.), and the evidence suggests that orgasmic response on the part of the patient may have been the intended therapeutic result.[6] Douche therapy, a method of directing a jet of pumped water at the pelvic area and vulva, was employed for similar purposes after hydrotherapy became popular in the eighteenth and nineteenth centuries.[7] The camouflage of the apparently sexual character of such therapy was accomplished through its medical respect ability and through creative definitions both of the diseases for which massage was indicated and of the effects of treatment. In the case of the electromechanical vibrator, the use of electrical power contributed the cachet of modernity and linked the instrument to older technologies of electrotherapeutics, in which patients received low-voltage electricity through electrodes attached directly to the skin or mucous membranes, and to light-bath therapy, in which electric light was applied to the skin in a closed cabinet. The electrotherapeutic association was explicitly invoked in the original term for the vibrator's inter changeable applicators, which were known as "vibratodes." Electrical treatments were employed in hysteria as soon as they were introduced in the eighteenth century, and remained in use as late as the 1920s.

Hysteria as a disease paradigm, from its origins in the Egyptian medical corpus through its conceptual eradication by American Psychological Association fiat in 1952, was so vaguely and subjectively defined that it might encompass almost any set of ambiguous symptoms that troubled a woman or her family. As its name suggests, hysteria as well as its "sister" complaint chlorosis were until the twentieth century thought to have their etiology in the female reproductive tract generally, and more particularly in the organism's response to sexual deprivation.[8] This physiological condition seems to have achieved epidemic proportions among women and girls, at least in the modern period.[9] Sydenham, writing in the seventeenth century, observed that hysteria was the most common of all diseases except fevers.[10]

In the late nineteenth century, physicians noted with alarm that from half to three-quarters of all women showed signs of hysterical affliction. Among the many symptoms listed in medical descriptions of the syndrome are anxiety, sense of heaviness in the pelvis, edema (swelling) in the lower abdomen and genital areas, wandering of attention and associated tendencies to indulge in sexual fantasy, insomnia, irritability, and "excessive" vaginal lubrication.[11]

The therapeutic objective in such cases was to produce a "crisis" of the disease in the Hippocratic sense of this expression, corresponding to the point in infectious diseases at which the fever breaks. Manual massage of the vulva by physicians or midwives, with fragrant oils as lubricants, formed part of the standard treatment repertoire for hysteria, chlorosis and related disorders from ancient times until the post-Freudian era. The crisis induced by this procedure was usually called the "hysterical paroxysm." Treatment for hysteria might comprise up to three-quarters of a physician's practice in the nineteenth century. Doctors who employed vulvular massage treatment in hysteria thus required fast, efficient and effective means of producing the desired crisis. Portability of the technology was also a desideratum, as physicians treated many patients in their homes, and only manual massage under these conditions was possible until the introduction of the portable battery-powered vibrator for medical use in the late 1880s.

Patients reported experiencing symptomatic relief after such treatments, and such conditions as pelvic congestion and insomnia were noticeably ameliorated, especially if therapy continued on a regular basis. A few physicians, including Nathaniel Highmore in the seventeenth century and Auguste Tripier, a nineteenth century electrotherapist, clearly recognized the hysterical paroxysm as sexual orgasm.[12] That many of their colleagues also perceived the sexual character of hysteria treatments is suggested by the fact that, in the case of married women, one of the therapeutic options was intercourse, and in the case of single women, marriage was routinely recommended.[13] "God-fearing physicians," as Zacuto expressed it in the seventeenth century, were expected to induce the paroxysm with their own fingers only when absolutely necessary, as in the case of very young single women, widows and nuns.[14] Many later physicians, however, such as the nineteenth century hydrotherapist John Harvey Kellogg, seem not to have perceived the sexual character of patient response. Kellogg wrote extensively about hydrotherapy and electrotherapeutics in gynecology. In his "Electrotherapeutics in Chronic Maladies," published in *Modern Medicine* in 1904, he describes "strong contractions of the abdominal muscles" in a female patient undergoing treatment, and similar reactions such that "the office table was made to tremble quite violently with the movement."[15] In their analysis of the situation, these physicians may have been handicapped by their failure to recognize that penetration is a successful means of producing orgasm in only a minority of women; thus treatments that did not involve significant vaginal penetration were not morally suspect. In effect, misperceptions of female sexuality formed part of the camouflage of the original manual technique that preceded the electromechanical vibrator. Insertion of the speculum, however, since it travelled the same path as the supposedly irresistible penis during intercourse, was widely criticized in the medical community for its purportedly immoral effect on patients.[16] That some questioned the ethics of the vulvular massage procedure is clear; Thomas Stretch Dowse quotes Graham as observing that "Massage of the pelvic organs should be intrusted to those alone who have 'clean hands and a pure heart'."[17] One physician, however, in an article significantly titled "Signs of Masturbation in the Female," proposed the application of an electrical charge to the clitoris as a test of salacious propensities in women. Sensitivity of the organ to this type of electrical stimulation, in his view, indicated secret indulgence in what was known in the nineteenth century as "a bad habit."[18] Ironically, such women were often treated electrically for hysteria supposedly caused by masturbation.

However they construed the benefits, physicians regarded the genital massage procedure, which could take as long as an hour of skilled therapeutic activity, as something of a chore, and made early attempts to mechanize it. Hydrotherapy, in the form of what was known as the "pelvic douche" (massage of the lower pelvis with a jet of pumped water), provided similar relief to the patient with reduced demands on the therapist. Doctors of the eighteenth and nineteenth centuries frequently recommended douche therapy for their women patients who could afford spa visits. This market was limited, however, as both treatment and travel were costly.[19] A very small minority of patients and doctors could afford to install hydrotherapeutic facilities in convenient locations; both doctor and patient usually had to travel to the spa. Electrically-powered equipment, when it became available, thus had a decentralizing and cost-reducing effect on massage treatment.

In the 1860s, some spas and clinics introduced a coal-fired steam powered device invented by a Dr. George Taylor, called the "Manipulator," which massaged the lower pelvis while the patient either stood or lay on a table.[20] This too required a considerable expenditure either by the physician who purchased the equipment or by the patient who was required to travel to a spa for treatment. Thus, when the electromechanical vibrator was invented two decades later in England by Mortimer Granville and manufactured by Weiss, a ready market already existed in the medical community.[21] Ironically, Mortimer Granville considered the use of his instrument on women, especially hysterics, a morally indefensible act, and recommended the device only for use on the male skeletal muscles.[22] Although his original battery-powered model was heavy and unreliable, it was more portable than water-powered massage and less fatiguing to the operator than manual massage.

Air-pressure models were introduced, but they required cumbersome tanks of compressed air, which needed frequent refilling. When line electricity became widely available, portable plug-in models made vibratory house calls more expeditious and cost effective for the enterprising physician. The difficulty of maintaining batteries in or out of the office was noted by several medical writers of the period predating the introduction of plug-in vibrators.[23] Batteries and small office generators were liable to fail at crucial moments during patient treatment, and required more engineering expertise for their maintenance than most physicians cared to acquire . . . Portable models using de or ac line electricity were available with a wide range of vibratodes, such as the twelve-inch rectal probe supplied with one of the Gorman firm's vibrators.

Despite its inventor's reservations, the Weiss instrument and later devices on the same principle were widely used by physicians for pelvic disorders in women and girls. The social camouflage applied to the older manual technology was carefully maintained in connection with the new, at least until the 1920s. The marketing of medical vibrators to physicians and the discussion of them in such works as Covey's *Profitable Office Specialties* addressed two important professional considerations: the respectability of the devices as medical instruments (including their reassuringly clinical appearance) and their utility in the fast and efficient treatment of those chronic disorders, such as pelvic complaints in women, that provided a significant portion of a physician's income.[24] The importance of a prestige image for electromechanical instrumentation, and its role in the pricing of medical vibrators is illustrated by a paragraph in the advertising brochure for the "Chattanooga," at $200 in 1904 the most costly of the physicians' office models:

> The Physician can give with the "Chattanooga" Vibrator a thorough massage treatment in three minutes that is extremely pleasant and beneficial, but this instrument is neither designed nor sold as a "Massage Machine." It is sold only to Physicians, and constructed for the express purpose of exciting the various organs of the body into activity through their central nervous supply. [25]

I do not mean to suggest that gynecological treatments were the only uses of such devices, or that all physicians who purchased them used them for the production of orgasm in female patients, but the literature suggests that a substantial number were interested in the new technology's utility in the hysteroneurasthenic complaints. The interposition of an official-looking machine must have done much to restore clinical dignity to the massage procedure. The vibrator was introduced in 1899 as a home medical appliance, and was by 1904 advertised in household magazines in suggestive terms we shall examine later on. It was important for physicians to be able to justify to patients the expense of $2–3 per treatment, as home vibrators were available for about $5.

The acceptance of the electromechanical vibrator by physicians at the turn of this century may also have been influenced by their earlier adoption of electrotherapeutics, with which vibratory treatment could be, and often was, combined.[26] Vibratory therapeutics were introduced from London and Paris, especially from the famous Hopital Salpetriere, which added to their respectability in the medical community.[27] It is worth noting as well that in this period electrical and other vibrations were a subject of great interest and considerable confusion, not only among doctors and the general public, but even among scientists like Tesla, who is reported to have fallen under their spell. " . . . [T]he Earth," he wrote, "is responsive to electrical vibrations of definite pitch just as a tuning fork to certain waves of sound. These particular electrical vibrations, capable of powerfully exciting the Globe, lend themselves to innumerable uses of great importance . . . "[28] In the same category of mystical reverence for vibration is Samuel Wallian's contemporaneous essay on "The Undulatory Theory in Therapeutics," in which he describes "modalities or manifestations of vibratory impulse" as the guiding principle of the universe. "Each change and gradation is not a transformation, as mollusk into mammal, or monkey into man, but an evidence of a variation in vibratory velocity. A certain rate begets a *vermis*, another and higher rate produces a *viper*, a *vertebrate*, a *vestryman*."[29]

In 1900, according to Monell, more than a dozen medical vibratory devices for physicians had been available for examination at the Paris Exposition. Of these, few were able to compete in the long term with electromechanical models. Mary L. H. Arnold Snow, writing for a medical readership in 1904, discusses in some depth more than twenty types, of which more than half are electromechanical. These models, some priced to the medical trade as low as $15, delivered vibrations from one to 7,000 pulses a minute. Some were floor-standing machines on rollers; others could be suspended from the ceiling like the modern impact wrench.[30] The more expensive models were adapted to either ac or dc currents. A few, such as those of the British firm Schall and Son, could even be ordered with motors custom-wound to a physician's specifications. Portable and battery-powered electromechanical vibrators were generally less expensive than floor models, which both looked more imposing as instruments and were less likely to transmit fatiguing vibrations to the doctor's hands.

Patients were treated in health spa complexes, in doctor's offices or their own homes with portable equipment. Designs consonant with prevailing notions of what a medical instrument should look like inspired consumer confidence in the physician and his apparatus, justified treatment costs, and, in the case of hysteria treatments, camouflaged the sexual character of the therapy. Hand or foot-powered models, however, were tiring to the operator; water-powered ones became too expensive to operate when municipalities began metering water in the early twentieth century. Gasoline engines and batteries were cumbersome and difficult to maintain, as noted above. No fuel or air-tank handling by the user was required for line electricity, in contrast with compressed air, steam and petroleum as power sources. In the years after 1900, as line electricity became the norm in urban communities, the electromechanical vibrator emerged as the dominant technology for medical massage.

Some physicians contributed to this trend by endorsing the vibrator in works like that of Monell, who had studied vibratory massage in medical practice in the United States and Europe at the turn of this century. He praises its usefulness in female complaints:

> . . . pelvic massage (in gynecology) has its brilliant advocates and they report wonderful results, but when practitioners must supply the skilled technic with their own fingers the method has no value to the majority. But special applicators (motor-driven) give practical value and office convenience to what otherwise is impractical.[31]

Other medical writers suggested combining vibratory treatment of the pelvis with hydro- and electrotherapy, a refinement made possible by the ready adaptability of the new electro mechanical technology.

At the same period, mechanical and electromechanical vibrators were introduced as home medical appliances. One of the earliest was the Vibratile, a battery-operated massage device advertised in 1899. Like the vibrators sold to doctors, home appliances could be handpowered, water-driven, battery or street-current apparatus in a relatively wide range of prices from $1.50 to $28.75. This last named was the price of a Sears, Roebuck model of 1918, which could be purchased as an attachment for a separate electrical motor, drawing current through a lamp socket, which also powered a fan, buffer, grinder, mixer and sewing machine. The complete set was marketed in the catalogue under the headline "Aids that Every Woman Appreciates." Vibrators were mainly marketed to women, although men were sometimes exhorted to purchase the devices as gifts for their wives, or to become door-to-door sales representatives for the manufacturer.[32]

The electromechanical vibrator was preceded in the home market by a variety of electrotherapeutic appliances which continued to be advertised through the twenties, often in the same publications as vibratory massage devices. Montgomery Ward, Sears Roebuck and the Canadian mail order department store T. Eaton and Company all sold medical batteries by direct-mail by the end of the nineteenth century. These were simply batteries with electrodes that administered a mild shock. Some, like Butler's Electro-Massage Machine, produced their own electricity with friction motors. Contemporaneous and later appliances sometimes had special features, such as Dr. H. Sanche's Oxydonor, which produced ozone in addition to the current when one electrode was placed in water. "Electric" massage rollers, combs and brushes with a supposedly permanent charge retailed at this time for prices between one and five dollars. Publications like the *Home Needlework Magazine* and *Men and Women* advertised these devices, as well as related technologies, including correspondence courses in manual massage.

Vibrators with water motors, a popular power source, as noted above, before the introduction of metered water, were advertised in such journals as *Modern Women*, which emphasized the cost savings over treatments by physicians and further emphasized the advantage of privacy offered by home treatment. Such devices were marketed through the teens in *Hearst's* and its successors, and in *Woman's Home Companion*.[33] Electromechanical vibrators were sold in the upper middle class market, in magazines typically retailing for between ten and fifteen cents an issue. As in the case of medical vibrators, models adapted to both ac and de current were more expensive than those for use with de only; all were fitted with screw-in plugs through the twenties.[34]

All types of vibrators were advertised as benefiting health and beauty by stimulating the circulation and soothing the nerves. The makers of the electromechanical American vibrator, for example, recommended their product as an" . . . alleviating, curative and beautifying agent . . . It will increase deficient circulation-develop the muscles-remove wrinkles and facial blemishes, and beautify the complexion."[35] Advertisements directed to male purchasers similarly emphasized the machine's advantages for improving a woman's appearance and disposition. And ad in a 1921 issue of *Hearst's* urges the considerate husband to "Give 'her' a Star for Christmas" on the grounds that it would be "A Gift That Will *Keep* Her Young and Pretty." The same device was listed in another advertisement with several other electrical appliances, and labelled "Such Delightful Companions!"[36] A husband, these advertisements seem to suggest, who presented his wife with these progressive and apparently respectable medical aids might leave for work in the morning secure in the knowledge that his spouse's day would be pleasantly and productively invested in self-treatment. Like other electrical appliance advertising of the time, electro mechanical vibrator ads emphasized the role of the device in making a woman's home a veritable Utopia of modern technology, and its utility in reducing the number of occasions, such as visiting her physician, on which she would be required to leave her domestic paradise.[37]

Advertisements for vibrators often shared magazine pages with books on sexual matters, such as Howard's popular *Sex Problems in Worry and Work* and Walling's *Sexology*, hand guns, cures for alcoholism and, occasionally, even personals, from both men and women, in which matrimony was the declared objective. Sexuality is never explicit in vibrator advertising; the tone is vague but provocative, as in the Swedish Vibrator advertisement in *Modern Priscilla* of 1913, offering "a machine that gives 30,000 thrilling, invigorating, penetrating, revitalizing vibrations per minute . . . Irresistible desire to own it, once you feel the living pulsing touch of its rhythmic vibratory motion." Illustrations in these layouts typically include voluptuously proportioned women in various states of *déshabillé*. The White Cross vibrator, made by a Chicago firm that manufactured a variety of small electrical appliances, was also advertised in *Modern Priscilla*, where the maker assured readers that "It makes you fairly tingle with the joy of living."[38] It is worth noting that the name "White Cross" was drawn from that of an international organization devoted to what was known in the early twentieth century as "social hygiene," the discovery and eradication of masturbation and prostitution wherever they appeared. The Chicago maker of White Cross appliances, in no known way affiliated with the organization, evidently hoped to trade on the name's association with decency and moral purity.[39] A 1916 advertisement from the White Cross manufacturer in *American Magazine* nevertheless makes the closest approach to explicit sexual claims when it promises that "All the keen relish, the pleasures of youth, will throb within you."[40] The utility of the product for female masturbation was thus consistently camouflaged.

Electromechanical vibrator advertising almost never appeared in magazines selling for less than 5 cents an issue (10 to 20 cents is the median range) or more than 25 cents. Readers of the former were unlikely to have access to electrical current; readers of the latter, including, for example, *Vanity Fair*, were more likely to respond to advertising for spas and private manual massage. While at least a dozen and probably more than twenty U.S. firms manufactured electromechanical vibrators before 1930, sales of these appliances were not reported in the electrical trade press. A listing from the February 1927 *NELA Bulletin* is typical; no massage equipment of any kind appears on an otherwise comprehensive list that includes violet-ray appliances.[41] A 1925 article in *Electrical World*, under the title "How Many Appliances are in Use?", lists only irons, washing machines, cleaners, ranges, water heaters, percolators, toasters, waffle irons, kitchen units and ironers.[42] *Scientific American* listed in 1907 only the corn popper, chafing dish, milk warmer, shaving cup, percolator and iron in a list of domestic electrical appliances.[43] References to vibrators were extremely rare even in popular discussions of electrical appliances.[44] The U.S. Bureau of the Census, which found 66 establishments manufacturing electro-therapeutic apparatus in 1908, does not dis aggregate by instrument type either in this category or in "electrical household goods." The 1919 volume, showing the electro medical market at a figure well over $2 million, also omits detailed itemization. Vibrators appear by name in the 1949 *Census of Manufactures*, but it is unclear whether the listing for them, aggregated with statistics for curling irons and hair dryers, includes those sold as medical instruments to physicians.[45] This dearth of data renders sales tracking of the electromechanical vibrator extremely difficult. The omissions from engineering literature are worth noting, as the electromechanical vibrator was one of the first electrical appliances for personal care, partly because it was seen as a safe method of self-treatment.[46]

The marketing strategy for the early electromechanical vibrator was similar to that employed for contemporaneous and even modern technologies for which social camouflage is considered necessary. Technologically, the devices so marketed differ from modern vibrators sold for explicitly sexual purposes only in their greater overall weight, accounted for by the use of metal housings in the former and plastic in the latter. The basic set of vibratodes is identical, as is the mechanical action. The social context of the machine, however, has undergone profound change. Liberalized attitudes toward masturbation in both sexes and increasing understanding of women's sexuality have made social camouflage superfluous.

In the case of the vibrator, the issue is one of acceptability, but there are many examples of similarly marketed technology of which the expected use was actually illegal. One of these, which shares with the vibrator a focus on women's sexuality, was that of "emmenagogues" or abortifacient drugs sold through the mail and sometimes even off the shelf in the first few decades of this century. Emmenagogues, called in pre-FDA advertising copy "cycle restorers," were intended to bring on the menses in women who were "late." Induced abortion by any means was of course illegal, but late menses are not reliable indicators of pregnancy. Thus, women who purchased and took "cycle restorers" might or might not be in violation of antiabortion laws; they themselves might not be certain without a medical examination. The advertising of these commodities makes free use of this ambiguity in texts like the following from *Good Stories* of 1933:

> Late? End Delay-Worry. American Periodic Relief Compound double strength tablets combine Safety with Quick Action. Relieve most Stubborn cases. No Pain. New discovery. Easily taken. Solves women's most perplexing problem. RELIEVES WHEN ALL OTHERS FAIL. Don't be discouraged, end worry at once. Send $1.00 for Standard size package and full directions. Mailed same day, special delivery in plain wrapper. American Periodic Relief Com pound Tablets, extra strength for stubborn cases, $2.00. Generous Size Package. New Book free.[47]

The rhetoric here does not mention the possibility of pregnancy, but the product's selling points would clearly suggest this to the informed consumer through the mentions of safety, absence of pain, and stubborn cases. The readers of the pulp tabloid *Good Stories* clearly did not require an explanation of "women's most perplexing problem."

Distilling technology raises similar issues of legality. During the Prohibition period, the classified section of a 1920 *Ainslee's* sold one and four gallon copper stills by mail, advising the customer that the apparatus was "Ideal for distilling water for drinking purposes, automobile batteries and industrial uses."[48] Modern advertisements for distilling equipment contain similar camouflage rhetoric, directing attention away from the likelihood that most consumers intend to employ the device in the production of beverages considerably stronger than water.[49]

Although changes in sexual mores have liberated the vibrator, social camouflage remains necessary for stills and many other modern commodities, including drug paraphernalia. The Deering Prep Kit, for example, is advertised at nearly $50 as a superlative device for grinding and preparing fine powders, "such as vitamin pills or spices."[50] Burglary tools are marketed in some popular (if lowbrow) magazines with the ad monition that they are to be used only to break into one's own home or automobile, in the event of having locked oneself out. The camouflage rhetoric seems to suggest that all prudent drivers and homeowners carry such tools on their persons at all times. Most recently, we have seen the appearance of computer software for breaking copy protection, advertised in terms that explicitly prohibit its use for piracy, although surely no software publisher is so naive as to believe that all purchasers intend to break copy protection only to make backup copies of legitimately purchased programs and data.[51] As in vibrator advertising, the product's advantages are revealed to knowledgeable consumers in language that disclaims the manufacturers' responsibility for illegal or immoral uses of the product.

The marketing of socially camouflaged technologies is directed to consumers who already understand the design purpose of the product, but whose legally and/or culturally unacceptable intentions in purchasing it cannot be formally recognized by the seller. The marketing rhetoric must extoll the pro duct's advantages for achieving the purchaser's goals-in the case of the vibrator, the production of orgasm-by indirection and innuendo, particularly with reference to the overall results, i.e., relaxation and relief from tension. The same pattern emerges in the advertisement of emmenagogues: according to the manufacturer, it is "Worry and Delay" that are ended, not pregnancy. In the case of software copyright protection pro grams, drug paraphernalia and distilling equipment, the expected input and/or output are simply misrepresented, so that an expensive finely-calibrated scale with its own fitted carrying case may be pictured in use in the weighing of jelly beans. As social values and legal restrictions shift, the social camouflaging of technologies may be expected to change in response, or to be dispensed with altogether, as in the case of the vibrator.

NOTES

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1. Harious versions of this paper have benefitted from comments and criticism from John Senior at the Bakken, Joel Tarr of Carnegie Mellon University, Shere Hite of Hite Research, Karen Reeds of Rutgers University Press, my former students at Clarkson University, and participants in the Social and Economic History Seminar, Queens University (Canada), the Hannah Lecture series in the History of Medicine at the University of Ottawa, and the 1986 annual meeting of the Society for the History of Technology with the Society for the Social Study of Science. Anonymous referees of this and other journals have also provided valuable guidance in structuring the presentation of my research results.
2. Sokolow, Jayme A., *Eros and Modernization: Sylvester Graham, Health Reform and the Origins of Victorian Sexuality in America*. Rutherford, NJ: Fairleigh Dickinson University Press, 1983, pp. 77–99; Haller, John S., and Robin Haller, *The Physician and Sexuality in Victorian America*. Urbana: University of Illinois Press, 1973, pp. 184–216; Greydanus, Donald E., "Masturbation; Historic Perspective," *New York State Journal of Medicine*, November 1980, vol. 80, no. 12, pp. 1892–1896; Szasz, Thomas, *The Manufacture of Madness*. New York: Harper and Row, 1977, pp. 180–206; Hare, E. H., "Masturbatory Insanity: The History of an Idea," *Journal of Mental Sciences*, 1962, vol 108, pp. 1–25; and Bullough, Vern, "Technology for the Prevention of 'Les Maladies Produites par Ia Masturbation,'" *Technology and Culture*, October 1987, vol. 28, no. 4, pp. 828–832.
3. On the vibrator in stag films, see Blake, Roger, *Sex Gadgets*. Cleveland: Century, 1968, pp. 33–46. An early postwar reference to the vibrator as an unabashedly sexual instrument is Ellis, Albert, *If this be Sexual Heresy*. New York: Lyle Stuart, 1963, p. 136.
4. Vibrators and dildoes are illustrated in Tabori, Paul, *The Humor and Technology of Sex*. New York: Julian Press, 1969; the dildo is discussed in a clinical context in Masters, William H., *Human Sexual Response*. Boston: Little, Brown, 1966. Vibrators of the period to which I refer in this essay are illustrated in Gorman, Sam J., *Electro Therapeutic Apparatus*. l0th ed. Chicago: Sam J. Gorman, c1912; Wappler Electric Manufacturing Co. Inc. *Wappler Cautery and Light Apparatus and Accessories*. 2nd ed. New York: Wappler Electric Manufacturing, 1914, pp. 7 and 42–43; Manhattan Electrical Supply Co., *Catalogue Twenty-Six: Something Electrical for Everybody*. New York: MESCO, n.d.; and Snow, Mary Lydia Hastings Arnold, *Mechanical Vibration and its Therapeutic Application*. New York: Scientific Author's Publication Company, 1904 and 1912. For modern vibrators, see Kaplan, Helen Singer, "The Vibrator: A Misunderstood Machine," *Redbook*, May 1984, p. 34; and Swarz, Mimi, "For the Woman Who Has Almost Everything," *Esquire*, July 1980, pp. 56–63.
5. See, for examples of such advertising, which in fact included a persistent abdominal emphasis, "Amazing New Electric Vibrating Massage Pillow," Niresk Industries (Chicago, IL) advertisement in Workbasket, October 1958, p. 95; "Don't be Fat," body massager (Spot Reducer) advertisement in Workbasket, September 1958, p. 90; and "Uvral Pneumatic Massage Pulsator," in *Electrical Age for Women*, January 1932, vol. 2, no. 7, pp. 275–276.
6. This therapy is extensively documented but rarely noted by historians. For only a few examples of medical discussions of vulvular massage in the hysteroneurasthenic disorders, see Aretaeus Cappadox, *The Extant Works of Aretaeus the Cappadocian*, ed. and transl. by Francis Adams. London: Sydenham Society, 1856, pp. 44–45, 285–287, and 449–451; Forestus, Alemarianus Petrus (Pieter van Foreest), *Observationem et Curationem Medicinalium ac Chirurgicarum Opera Omnia*. Rothomagi: Bertherlin, 1653, vol. 3, book 28, pp. 277–340; Galen of Pergamon, *De Locis Affectis*, transl. by Rudolph Siegel. Basel and New York: S. Karger, 1976, book VI, chapter II: 39; and Weber, A. Sigismond, *Traitement par l'Hectricite et le Massage*. Paris: Alex Coccoz, 1889, pp. 73–80. Of modern scholars, only Audrey Eccles discusses this therapy in detail in her *Obstetrics and Gynaecology in Tudor and Stuart England*. London and Canberra: Croom Helm, 1982, pp. 76–83.
7. Baruch, Simon, *The Principles and Practice of Hydrotherapy: A Guide to the Application of Water in Disease*. New York: William Wood and Company, 1897, pp. 101, 211, 248 and 365; Dieffenbach, William H., *Hydrotherapy*. New York: Rebman, 1909, pp. 238–245; Good Health Publishing Company. *20th Century Therapeutic Appliances*. Battle Creek, MI: Good Health Publishing, 1909, pp. 20–21; Hedley, William Snowdon. *The Hydro-Electric Methods in Medicine*. London: H. K. Lewis, 1892; Hinsdale, Guy, *Hydrotherapy*. Philadelphia and

London: W.B. Saunders Company, 1910, p. 224; Kellogg, John Harvey, *Rational Hydrotherapy*. Philadelphia: Davis, 1901; Irwin, J.A., *Hydrotherapy at Saratoga*. New York: Casell, 1892, pp. 85–134 and 246–248; Pope, Curran, *Practical Hydrotherapy: A Manual for Students and Practitioners*. Cincinnati, OH: Lancet-Clinic Publishing Co., 1909, pp. 181–192 and 506–538; and Trail, Russell Thacher, *The Hydropathic Encyclopedia*. New York: Fowlers and Wells, 1852, pp. 273–295. Women were reportedly in the majority as patients at spas, and some were owned by women entrepreneurs and/or physicians. See Whyman, T., "Visitors to Margate in the 1841 Census Returns," *Local Population Studies*, vol. 8, 1972, p. 23. Since at least the time of Jerome, baths and watering places have had a reputation for encouraging unacceptable expressions of sexuality. For female masturbation with water, see Aphrodite, J. (pseud.), *To Turn You On*: *39 Sex Fantasies for Women*. Secaucus, NJ: Lyle Stuart, Inc., 1975, pp. 83–91; and Halpert, E., "On a Particular Form of Masturbation in Women: Masturbation with Water," *Journal of the American Psychoanalytic Association*, 1973, vol. 21, p. 526.

8. A bibliography of nineteenth century American works on women and sexuality in relation to hysteria is available in Sahli, Nancy, *Women and Sexuality in America: A Bibliography*. Boston: Hall, 1984. See also Shorter, Edward, "Paralysis: the Rise and Fall of the 'Hysterical' Symptom," *Journal of Social History*, Summer 1986, vol. 19, no. 4, pp. 549–582; Satow, Roberta. "Where Has All the Hysteria Gone?" *Psychoanalytic Review*, 1979–80, vol. 66, pp. 463–473; Bourneville, Desire Magloire and P. Regnard. *Iconographie Photographique de la Salpetriere*. Paris: Progres-Medical, 1878, vol. 2, pp. 97–219; Charcot, Jean-Martin. *Clinical Lectures on Certain Diseases of the Nervous System*, transl. by E.P. Hurd. Detroit: G.S. Davis, 1888, p. 141; Ellis, Havelock. *Studies in the Psychology of Sex*, vol. I, New York: Random House, 1940, p. 270; Krohn, Alan, *Hysteria: The Elusive Neurosis.* New York: International Universities Press, 1978, pp. 46–51; McGrath, William J., *Freud's Discovery of Psychoanalysis: The Politics of Hysteria.* Ithaca, NY: Cornell University Press, 1986, pp. 152–172; Veith, Ilza, *Hysteria: The History of a Disease*. Chicago: University of Chicago Press, 1965; Wittels, Franz, *Freud and His Time*. New York: Grosset and Dunlap, 1931, pp. 215–242; and Ziegler, Dewey and Paul Norman, "On The Natural History of Hysteria in Women," *Diseases of the Nervous System*, 1967, vol. 15, pp. 301–306.
9. Bauer, Carol, "The Little Health of Ladies: An Anatomy of Female Invalidism in the Nineteenth Century," *Journal of the American Medical Woman's Association,* October 1981, vol. 36, no. 10, pp. 300–306; Ehrenreich, Barbara and D. English, *Complaints and Disorders: The Sexual Politics of Sickness*. Old Westbury, NY: Feminist Press, 1973, pp. 15–44; and Trail, Russell Thacher, *The Health and Diseases of Women.* Battle Creek, MI: Health Reformer, 1873, pp. 7–8.
10. Sydenham Thomas, "Epistolary Dissertation on Hysteria," in *The Works of Thomas Sydenham,* transl. by R.G. Latham. London: Printed for the Sydenham Society, 1848, vol. 2, pp. 56 and 85: and Payne, Joseph Frank, *Thomas Sydenham.* New York: Longmans, Green and Co., 1900, p. 143.
11. Only a minority of writers on hysteria associated the affliction with paralysis until Freud made this part of the canonical disease paradigm in the twentieth century.
12. Gall, Franz Josef, *Anatomie et Physiologie du Systeme Nerveux en General.* Paris: F. Schoen, 1810–1819, vol. 3, p. 86; Tripier, Auguste Elisabeth Philogene, *Leçons Cliniques sur les Maladies de Femmes.* Paris: Octave Doin, Editeur, 1883, pp. 347–351; Highmore, Nathaniel, *de Passione Hysterica et Affectione Hypochondriaca.* Oxon.: Excudebat A. Lichfield impensis R. Davis, 1660, pp. 20–35; and Ellis, *Studies in the Psychology of Sex,* vol. I, p. 225; see also Briquet, Pierre, *Traite Clinique et Therapeutique de l'Hysterie.* Paris: J.B. Bailliere et Fils, 1859, pp. 137–138, 570 and 613.
13. Cullen, William, *First Lines in the Practice of Physic.* Edinburgh: Bell, Bradfute, etc., 1791, pp. 43–47; Burton, Robert, *The Anatomy of Melancholy,* Floyd Dell and Paul Jordan Smith, eds. New York: Farrar and Rinehart, 1927, pp. 353–355; Horst, Gregor, *Dissertationem . . . inauguralem De Mania. . . . Gissae: typis Viduae Friederici Kargeri,* 1677, pp. 9–18; King, A.F.A., "Hysteria," *American Journal of Obstetrics,* May 18, 1891, vol. 24, no. 5, pp. 513–532; *Medieval Woman's Guide to Health,* transl. by Beryl Rowland. Kent, OH: Kent State University Press, 1981, pp. 2, 63 and 87; Pinel, Philippe, *A Treatise on Insanity,* transl. by D.D. Davis. Facsimile edition of the London 1806 edition; New York: Hafner, 1962, pp. 229–230; and Reich, Wilhelm, *Genitality in the Theory and Therapy of Neurosis,* transl. by Philip Schmitz. New York: Farrar, Straus and Giroux, 1980 (reprint of 1927 edition), pp. 54–55 and 93.
14. Zacuto, Abraham. *Praxis Medica Admiranda.* London: Apud Ioannem-Antonium Huguetan, 1637, p. 267. Zacuto is at pains to point out that some physicians regard vulvular massage as indecent: "Num autem ex hac occasione, liceat Medico timenti Deum, sopitis pariter cunctis sensibus, & una abolita respiratione in foeminis quasi animam agentibus, seu in maximo

vitae periculo constitutus, veneficium illud semen, foras ab utero, titillationibus, & frictionbius partium obscoenarium elidere, different eloquenter . . ."

15. October-November, p. 4. Kellogg's background is described in detail in Schwarz, Richard W., *John Harvey Kellogg, MD.* Nashville: Southern Publishing Association, c1970.
16. Women who regularly undergo the discomfort of gynecological examination with this instrument are justifiably amused by its nineteenth century mythology. For an example of conservative views on the speculum, see Griesinger, Wilhelm, *Mental Pathology and Therapeutics,* transl. by C. Lockhart Robinson and James Rutherford. London: New Sydenham Society, 1867, p. 202. On the inefficiency of penetration as a means to female orgasm, the standard modern work is of course Hite, Shere, *The Hite Report on Female Sexuality.* New York: MacMillan Company, 1976, but the phenomenon was widely noted by progressive physicians and others before the seventies. Most of these latter, however, regarded the failure of penetration to fully arouse about three-quarters of the female population as either a pathology on the women's part or as evidence of a natural diffidence in the female. Hite is the first to point out that the experience of the majority constitutes a norm, not a deviation. For examples of various male views on this subject, see Hollender, Marc H, "The Medical Profession and Sex in 1900," *American Journal of Obstetrics and Gynecology,* vol. 108, no. I, 1970, pp. 139–148; Degler, Carl, "What Ought to be and What Was," *American Historical Review,* vol. 79, 1974, pp. 1467–1490; and his *At Odds: Women and the Family in America from the Revolution to the Present.* New York: Oxford University Press, 1980, pp. 249–278; and Tourette, Gilles de Ia., *Traite Clinique et Therapeutique de l'Hysterie Paroxystique.* Paris: Pion, 1895, vol. I, p. 46. Feminine views are seldom recorded before this century; a few examples are those reported by Katherine B. Davis, summarized in Dickson, Robert L. and Henry Pierson, "The Average Sex Life of American Women," *Journal of the American Medical Association,* vol. 85, 1925, pp. 113–117; Lazarsfeld, Sofie, *Woman's Experience of the Male.* London: Encyclopedic Press, 1967, pp. 112, 181,271 and 308. It has also been noted that few women have difficulty achieving orgasm in masturbation, and that the median time to orgasm in masturbation is substantially the same in both sexes: Kinsey, Alfred Charles, *Sexual Behavior in the Human Female.* Philadelphia: Saunders, 1953, p. 163.
17. Dowse, Thomas Stretch, *Lectures on Massage and Electricity in the Treatment of Disease.* Bristol: John Wright and Co., 1903, p. 181.
18. Smith, E. H., in *Pacific Medical Journal,* February 1903.
19. For examples of spa expenses in the United States, see Cloyes, Samuel A., *The Healer; the Story of Dr. Samantha S. Nivison and Dryden Springs, 1820–1915.* Ithaca, NY: DeWitt Historical Society of Tompkins County, 1969, p. 24; Karsh, Estrellita, "Taking the Waters at Stafford Springs," *Harvard Library Bulletin,* July 1980, vol. 28, no. 3, pp. 264–281; McMillan, Marilyn, "An Eldorado of Ease and Elegance: Taking the Waters at White Sulphur Springs," *Montana,* vol. 35, Spring 1985, pp. 36–49; and Meeks, Harold, "Smelly, Stagnant and Successful: Vermont's Mineral Springs," *Vermont History,* 1979, vol. 47, no. I, pp. 5–20.
20. Taylor wrote indefatigably on the subject of physical therapies for pelvic disorders, and devoted considerable effort to the invention of mechanisms for this purpose. See Taylor, George Henry, *Diseases of Women.* Philadelphia and New York: G. McClean, 1871; *Health for Women.* New York: John B. Alden, 1883 and eleven subsequent editions; "Improvements in Medical Rubbing Apparatus," U.S. Patent 175,202 dated March 21, 1876; *Mechanical Aids in the Treatment of Chronic Forms of Disease.* New York: Rodgers, 1893; *Pelvic and Hernial Therapeutics.* New York: J. B. Alden, 1885; and "Movement Cure," U.S. Patent 263,625 dated August 29, 1882.
21. An example of the early Weiss model is available for study at the Bakken (Library and Museum), Minneapolis, MN, accession number 82.100.
22. Mortimer Granville, Joseph, *Nerve-Vibration and Excitation as Agents in the Treatment of Functional Disorders and Organic Disease.* London: J.&A. Churchill, 1883, p. 57; his American colleague Noble Murray Eberhart advises against vibrating pregnant women "about the generative organs" for fear of producing contractions. See his *A Brief Guide to Vibratory Technique.* 4th ed. rev. and enl. Chicago: New Medicine Publication, c1915, p. 59. For examples of enthusiastic endorsements of the new technology, see Gottschalk, Franklin Benjamin, *Practical Electro-Therapeutics.* Hammond, IN: F. S. Betz, 1904; the same author's *Static Electricity, X-Ray and Electro-Vibration: Their Therapeutic Application.* Chicago: Eisele, 1903; *International Correspondence Schools, A System of Electrotherapeutics.* Scranton, PA: International Textbook Company, 1903, vol. 4; Matijaca, Anthony, *Principles of Electro-Medicine, Electro-Surgery*

and Radiology. Tangerine, FL, Butler, NJ and New York, NY: Benedict Lust, 1917; Monell, Samuel Howard, *A System of Instruction in X-Ray Methods and Medical Uses of Light, Hot Air, Vibration and High Frequency Currents*. New York: E. R. Pelton, 1902; Pilgrim, Maurice Riescher, *Mechanical Vibratory Stimulation; its Theory and Application in the Treatment of Disease*. New York City: Lawrence Press, c1903; Rice, May Cushman, *Electricity in Gynecology*. Chicago: Laing, 1909; Rockwell, Alphonse David, *The Medical and Surgical Uses of Electricity*. New ed. New York: E. G. Treat, 1903; Snow, *Mechanical Vibration and its Therapeutic Application;* Waggoner, Melanchthon R. *The Note Book of an Electro-Therapist*. Chicago: Mcintosh Electrical Corporation, 1923; Wallian, Samuel Spencer, *Rhythmotherapy*. Chicago: Ouellette Press, 1906; and the same author's "Undulatory Theory in Therapeutics," *Medical Brief,* May and June, 1905.

23. See for example, Smith, A. Lapthorn, "Disorders of Menstruation," in *An International System of Electro-Therapeutics,* Horatio Bigelow, ed. Philadelphia: F. A. Davis, 1894, p. G163.
24. Covey, Alfred Dale, *Profitable Office Specialities*. Detroit: Physicians Supply Co., 1912, pp. 16, 18, and 79–95; Bubier, Edward Trevert, *Electro-Therapeutic Hand Book*. New York: Manhattan Electric Supply Co., 1900; Duck, J. J. Co., *Anything Electrical: Catalog No. 6*. Toledo, OH: J. J. Duck, 1916, p. 162; Golden Manufacturing Co., *Vibration: Nature's Great Underlying Force for Health, Strength and Beauty*. Detroit, MI: Golden Manufacturing Co., 1914; Gorman, Sam J. Co. *Physician's Vibragenitant*. Chicago: Sam J. Gorman and Co., n.d.; Keystone Electric Co., *Illustrated Catalogue and Price List of Electro-Therapeutic Appliances . . . etc.* Philadelphia: Keystone Electric Company, c1903, pp.63–66; Schall and Son, Ltd., *Electro-Medical Instruments and their Management* . . . 17th ed. London and Glasgow: Schall and Son, 1925; Vibrator Instrument Co., *A Treatise on Vibration and Mechancial Stimulation*. Chattanooga, TN: Vibrator Instrument, 1902; Vibrator Instrument Co. Clinical Dept., *A Course on Mechanical Vibratory Stimulation*. New York City: Vibrator Instrument, 1903; "Vibratory Therapeutics," *Scientific American,* vol. 67, October 22, 1892, p. 265. Most of these manufacturers were quite respectable instrument firms; see Davis, Audrey B., *Medicine and its Technology: An Introduction to the History of Medical Instrumentation*. Westport, CT: Greenwood Press, 1981, p. 22.
25. Vibrator Instrument Company, *Chattanooga Vibrator*. Chattanooga, TN: Vibrator Instrument, 1904, pp. 3 and 26.
26. Vigouroux, Auguste, *Etude sur la Resistance Electrique chez les Melancoliques*. Paris: J. Rueff et Cie, Editeurs, 1890; Cowen, Richard J., *Electricity in Gynecology*. London: Bailiere, Tindall and Cox, 1900; Engelmann, George J., "The Use of Electricity in Gynecological Practice," *Gynecological Transactions,* vol. 11, 1886; Reynolds, David V., "A Brief History of Electrotherapeutics," in *Neuroelectric Research,* D.V. Reynolds and A. Sjoberg, eds. Springfield, IL: Thomas, 1971, pp. 5–12; and Shoemaker, John V., "Electricity in the Treatment of Disease," *Scientific American Supplement,* January 5, 1907, vol. 63, pp. 25923–25924.
27. "Vibratory Therapeutics," *Scientific American,* vol. 67, October 22, 1892, p. 265.
28. O'Neill, John J., *Prodigal Genius: The Life of Nikola Testa*. New York: Ives Washburn, Inc., 1944, p. 210.
29. *Medical Brief,* May 1905, p. 417. See also the theory of light vibrations employed in the Master Electric Company's advertising brochure *The Master Violet Ray*. Chicago: n.d.
30. Monell, *A System of Instruction. . . ,* p. 595; Snow, *Mechanical Vibration*.
31. Monell, *A System of Instrumentation* . . . , p. 591.
32. See for example, "Wanted, Agents and Salesman . . . " *Swedish Vibrator Company, Modern Priscilla,* April 1913, p. 60.
33. "Agents! Drop Dead Ones!" Blackstone Water Power Vacuum Massage Machine, *Hearst's,* April 1916, p. 327; and "Hydro Massage" Warner Motor Company, *Modern Women,* vol. 11, no. I, December 1906, p. 190.
34. Wall receptacles are a relatively late introduction. See Schroeder, Fred E., "More 'Small Things Forgotten:' Domestic Electrical Plugs and Receptacles, 1881–1931," *Technology and Culture,* July 1986, vol. 27, no. 3, pp. 525–543.
35. "Massage is as old as the hills . . . ,"*American Vibrator Company, Woman's Home Companion,* April 1906, p. 42.
36. "Such Delightful Companions!" *Star Electrical Necessities,* 1922, reproduced in Jones, Edgar R., Those were the Good Old Days. New York: Fireside Books, 1959, unpaged; and "A Gift that will Keep her Young and Pretty," Star Home Electric Massage, *Hearst's International,* December 1921, p. 82.
37. See for example, the Ediswan advertisement in *Electrical Age for Women,* January 1932, vol. 2, no. 7, p. 274, and review on page 275 of the same publication.

38. "Vibration is Life," Lindstrom-Smith Co., *Modern Priscilla,* December 1910, p. 27.
39. Pivar, David J. *Purity Crusade: Sexual Morality and Social Control,* 1868–1900. Westport, CT: Greenwood Press, 1973, pp. 110–117.
40. See also *American Magazine,* December 1912, vol. 75, no. 2, January 1913; vol. 75, no. 3, May 1913; vol. 75, no. 7, p. 127; *Needlecraft,* September 1912, p. 23; *Home Needlework Magazine,* October 1908, p. 479, October 1915, p. 45; *Hearst's,* January 1916, p. 67, February 1916, p. 154, April 1916, p. 329; June 1916, p. 473, and *National Home Journal,* September 1908, p. 15.
41. Davidson, J. E., "Electrical Appliance Sales During 1926," *NELA Bulletin,* vol. 14, no. 2, pp. 119–120.
42. December 5, 1925, vol. 86, p. 1164. See also Hughes, George A. "How the Domestic Electrical Appliances are Serving the Country," *Electrical Review,* June 15, 1918, vol. 72, p. 983; Edkins, E. A., "Prevalent Trends of Domestic Appliance Market," *Electrical World,* March 30, 1918, pp. 670–671; and "Surveys Retail Sale of Electrical Appliances," *Printer's Ink,* vol. 159, May 19, 1932, p. 35.
43. "Electrical Devices for the Household," *Scientific American,* January 26, 1907, vol. 96, p. 95.
44. The vibrator is not included in extensive lists of appliances in Lamborn, Helen, "Electricity for Domestic Uses," *Harper's Bazaar,* April 1910, vol. 44, p. 285; and Knowlton, H.S., "Extending the Uses of Electricity," *Cassier's Magazine,* vol. 30, June 1906, pp. 99–105.
45. U.S. Bureau of the Census. *Census of Manufactures,* 1908, 1919, and 1947, pp. 216–217, 203, and 734 and 748 respectively.
46. On the early history of appliances, see Lifshey, Earl, *The Housewares Story.* Chicago: Housewares Manufacturers' Association, 1973. For the safety issue, see "Eiectromedical Apparatus for Domestic Use," *Electrical Review,* October 22, 1926, p. 682.
47. *Good Stories,* October 1933, p. 2; see also similar advertisement in the same issue for Dr. Roger's Relief Compound, p. 12.
48. "Water Stills," *Ainslee's Magazine,* October 1920. p. 164.
49. See for example, Damark International, Inc., *Catalog B-330.* Minneapolis, MN: Damark International, 1988, p. 7, which emphasizes the "Aiambiccus Distiller's" usefulness for distilling herbal extracts.
50. *Mellow Mail Catalogue.* Cooper Station, New York City: 1984, pp. 32–39.
51. Levy, Steven, *Hackers: Heroes of the Computer Revolution.* Garden City, NY: Anchor Press/Doubleday, 1984, p. 377.

CHAPTER 11

The Need to Bleed? A Feminist Technology Assessment of Menstrual-Suppressing Birth Control Pills

Jennifer Aengst and Linda L. Layne

Seasonale[1], a low-dose, extended-regimen, birth control pill approved by the U.S. Federal Drug Administration (FDA) in September 2003, regulates menstruation so that it occurs only four times a year. Seasonale shares the same chemical makeup as monthly birth control pills, so it shares with conventional pills a high level of contraceptive efficacy (99 percent if used consistently)[2], and a number of possible health benefits (a reduced risk of cancers of the ovaries and uterus, pelvic inflammatory disease, ovarian cysts, ectopic pregnancy, and noncancerous lumps or cysts of the breast) (Duramed 2005b). Like conventional pills, Seasonale also increases the risk of "blood clots, stroke, and heart attack," all of which are greater among smokers, and like other oral contraceptives, Seasonale "doesn't protect against HIV or other sexually transmitted diseases" (Duramed 2005a).[3]

The unique purported benefit of Seasonale is that it offers women "Fewer Periods. More Possibilities,"[4] and it is this aspect of the technology on which our analysis focuses. Several other birth control pills with a range of menstrual-suppressing features are also coming to market[5] including Seasonique (similar to Seasonale), Lybrel (which suppresses indefinitely), and Yaz and Loestrin24Fe, both of which are taken twenty-four, instead of twenty-one, days, followed by four "reminder" placebo pills, therefore offering shorter (three-day), lighter, monthly periods. Issues raised by Seasonale apply equally to these and other menstrual-suppressing birth control technologies.[6]

The subject of menstrual suppression has been debated in both medical and popular literature. Several of these articles make use of the responses of over 900 visitors to the online Museum of Menstruation and Women's Health (MUM) to the question, "Would you stop menstruating indefinitely—for years, maybe—if you could start up again easily if you wanted a child?," which has been posed on this Web site since 2000.[7] We too draw on these data, along with a small survey of Aengst's social network,[8] and a review of the writings of advocates and opponents to show how physical and attitudinal differences among women complicate the question of "feminist technologies."[9] We also consider how different feminist theories shape the evaluation of technologies for menstrual suppression as we address the meanings of "nature," "normality," and "necessity," gender norms, and the appropriation of technology. The result is what Layne calls a "feminist technology assessment."

THE EXPERTS: FOR AND AGAINST MENSTRUAL SUPPRESSION

Women's health experts are widely divided on the issue of menstrual-suppressing birth control pills. The most common argument made in favor of suppression is that promoted by a Brazilian gynecologist, Elsimar Coutinho, and Sheldon J. Segal, an endocrinologist at the Population Council.[10] Coutinho did research in 1959 at the Rockefeller Institute for Medical Research with Dr. George Corner, one of the codiscoverers of progesterone. After returning to Brazil he conducted a clinical trial of Depo Provera. The drug was being tested for the prevention of threatened spontaneous abortion and premature delivery, at which it failed, but the trial inadvertently revealed the drug's capacity to suppress ovulation and menstruation. He then conducted a series of clinical trials for the maker, Upjohn, on volunteers who did not want to become pregnant, which showed how Depo Provera could prevent ovulation and menstruation for one, three, or six months depending on the dose (Coutinho and Segal 1999, 9). This side effect, referred to in the women's health movement as a "menstrual disturbance" (Hardon, this volume) is lauded by Coutinho and Segal as a marketable benefit of the drug.

The argument put forward in their book is one that had been articulated nearly twenty years earlier by Dr. Barbara Harrell (1981, 816): menstruation is "relatively uncommon" for preindustrial women because of frequent pregnancies and prolonged lactation resulting in amenorrhea and that "continuous menstrual cycling is not a natural attribute of human females." Coutinho and Segal (1999, 2) go further and suggest that "repeated menstruation" could be harmful to women's health (1999, 5) and that suppressing menstruation would have health benefits for "women who suffer from anemia, endometriosis, or PMS."[11]

They end their book celebrating the liberatory feminist potential of this drug. They envision a future in which women use menstrual-suppressing drugs, and as they grow "more confident, would lengthen the menstruation-free interval . . . other women would be encouraged to try" and medical researchers would be motivated to find more advanced methods. . . . This would forge a major advance in women's health, led by women. The pioneer feminist Margaret Sanger wrote, 'No woman is completely free unless she has control over her own reproductive system.' Let this new freedom begin" (1999, 1603–4).

Other supporters, Charlotte Ellertson, Ph.D. (also of the Population Council), and Sarah Thomas, B.A.,[12] argue that the "view that menses, even debilitating ones, are normal, stigmatizes menstrual disorders and deprives millions of women of legitimate and easily available help" (Thomas and Ellertson 2000, 924). Using the liberal feminist tropes of personal control, choice, and liberation, they construe menstrual suppression as feminist, asserting that the use of contraceptives such as Seasonale "lets women *control* their hormonal profiles as well as whether and when they *choose* to bleed" and that menstrual suppression will "contribute to happier, *less encumbered lives*" (2000, 922, emphasis added).[13] They situate menstrual suppression as just one of several choices women routinely make about menstrual and birth control products and in so doing suggest that the decision to suppress menstruation is a simple consumer choice, no different than deciding which type of sanitary product to buy (2000, 923).[14]

In the twenty-two American and Canadian articles published in the popular press between the 1999 publication of Coutinho and Segal's book and the FDA approval of Seasonale in 2003, advocates of menstrual suppression like these were quoted "twice as often as opponents" (Johnston-Robledo et al. 2006) and in 40 to 50 percent of the articles (2006, 357), proponents praised the way this drug "expand[ed] women's choices" and gave women "more control over their lives, menstrual cycles or reproductive health."

Those against argue that there are uncertainties about the effects of long-term usage, and note that menstrual-suppressing drugs like Seasonale reinscribe negative attitudes toward women's bodily processes (Prior and Hitchcock 2006).[15] Christine Hitchcock, a research associate at the Center for Menstrual Cycle and Ovulation Research, points out that the same hormones that create menstrual cycles "act in the brain, bones and skin" (Saul 2007, C4) and so altering them may contribute to unknown long-term health risks for women. She also worries about "the idea that you can turn your body on and off like a tap" (Saul 2007, A1). The Society for Menstrual Cycle Research issued a position statement on menstrual suppression in 2003 that cautioned that more research was needed regarding not only the medical consequences of use but also the psychosocial dimensions of suppression before women could make informed decisions. The authors recognized "that menstrual suppression may be a useful option for women with severe menstrual cycle problems such as endometriosis," but argued against use that would suppress "normal, healthy menstrual cycle[s]" and expressed special concern for the use of extended oral contraceptives by adolescents.

Opponents also point out that Seasonale does not deliver on the purported "convenience of four periods a year." During the first year of use, women are "more likely to have breakthrough bleeding (which varies from slight spotting to a flow much like a regular period) than with a 28-day birth control pill" (Duramed 2005b). In fact, during the first year, "total bleeding days are similar to a traditional birth control pill" (Duramed 2005b). They also point out that skipping the conventional monthly placebo pills puts users more at risk for breast cancer, heart attacks, and strokes. A further negative is the expense—one package of a single cycle of Seasonale (ninety-one tablets) ranges from $100 to over $200 (generic or brand name), which may or may not be covered by insurance. This is in contrast to monthly birth control pills that typically range in cost between twenty to thirty dollars per month, the equivalent of sixty to ninety dollars for three months.[16]

Opponents also voice concern about use by teens[17] who are perceived to be especially vulnerable to marketing efforts because they are more likely to have negative attitudes toward menstruation (Johnston-Robledo et al. 2006, 354), be uncomfortable with their bodies, and particularly concerned about issues of personal hygiene and the scrutiny and judgment of others. Furthermore, since many teens are only sexually active intermittently, the health risks of continuous birth control pills are considered an unnecessary risk. Contributors to the MUM Web site mention special concern for this population and observed that they themselves probably would have welcomed the chance to suppress when they were young, but now that they are older/wiser, see the harm in it.

Underlying this debate are conflicting interpretations of both Seasonale's and women's relationship to nature. Women have long been culturally associated with nature, and feminists have been, and continue to be, deeply divided about whether this association is beneficial or detrimental for women's status. Seasonale thus makes a particularly good case for considering the notion of "feminist technology" through the lenses of diverse feminist theories.

IS MENSTRUATION NATURAL?

Proponents of suppression challenge the naturalness of monthly menstruation. They suggest that the view that menstruation is natural is simply a myth (Thomas and Ellertson 2000, 922), and urge us to reexamine "the credo that frequent and prolonged menstruation is the 'natural' state." Other times, they agree with opponents that menstruation is natural but differ with them on the meaning and value attributed to this. Whereas opponents to suppression believe that menstruation is natural and thus should not be tampered with, supporters of suppression scorn such views. For instance Coutinho and Segal criticize those who "adopt the view that since it is 'natural' for women to menstruate, it must be good for their health. They seem to believe that 'you can't fool Mother Nature!' The logic is that things natural, such as pain, physical or mental impairment, or even disease should be accepted simply because they are natural" (1999, 138).

Similarly, Thomas and Ellertson cast menstruation as natural but treat the natural as something we can and often should change: "Health professionals and women ought to view menstruation as they would any other naturally occurring but frequently undesirable condition"; that is, by "eliminating" it.[18] They argue that "[s]uppression should be just one option for women and those who choose not to avail themselves of it certainly deserve to have their choices respected[19] . . . just as do women who choose to use 'natural' family planning methods in place of hormonal ones or 'natural' menstrual sponges in place of commercial tampons or sanitary pads" (2000, 923). In this passage they treat menstruation as natural but destabilize "natural" by putting it in quotes, liken menstruating (which most American women do) to the use of natural birth control methods and natural menstrual sponges (which most American women do not use), and suggest choosing not to take a drug to suppress "natural" monthly menses is something only a small portion of women would embrace.

MIMICKING NATURE

Both traditional birth control pills and Seasonale create planned periods that deviate from the normal menstrual cycle while appearing to mimic nature. With traditional birth control pills, women take seven days of placebo sugar pills after twenty-one days of oral contraceptives, which allows them to mimic the "normal"—that is, "natural"—monthly cycle. Seasonale users take the placebo pills after eighty-four days. The substitution of four so-called seasonal periods with Seasonale (instead of, say, five a year), is also clearly designed to appear "natural."

To counter the possible perception of unnaturalness of four periods, the makers of Seasonale stress that the monthly periods with traditional birth control pills are not in fact "real," "natural," or "normal" periods. As a promotional brochure for Seasonale explains, "when you take the Pill, you don't ovulate. This means your ovaries don't release an egg, the lining of your uterus doesn't build up, and you don't get a menstrual period. Instead, you get a 'Pill period'" (Duramed 2005b). Women using the pill, whether traditional or extended-regimen, simply "appear to menstruate."[20] The seven-day placebo week was historically included because of cultural notions of "normalcy." According to Carolyn Westhoff, M.D, professor of obstetrics and gynecology at Columbia University, "It was thought that women would find it reassuring to get a period every month. The week off was inserted not for biological reasons, but just to make women and doctors more comfortable" (Davis 2003).

In a *New Yorker* profile of John Rock, the devout Catholic physician who was one of the inventors of the birth control pill, Gladwell explains that one of the reasons Rock believed that the pill would be acceptable to the church is that it "was a 'natural' method of birth control . . . Progestin . . . is nature's contraceptive. And what was the Pill? Progestin in tablet form" (Gladwell 2000, 2).[21] Furthermore, Pope Pius XII had sanctioned the rhythm method in 1951 because he deemed it a "natural" method of regulating procreation, and Rock saw the pill as an extension of this. He "insisted on a twenty-eight-day cycle for his pill" in order to preserve the natural "menstrual rhythms" (Gladwell 2000).

IS MENSTRUATION NECESSARY?

Proponents of menstrual suppression argue that menstruation is unnecessary. According to Dr. Mitchell Creinin, director of family planning in the Obstetrics and Gynecology Department of the University of Pittsburgh's Magee-Women's Hospital, "The idea that a woman 'needs' to have a period is folklore" (Shaw 2003). Coutinho and Segal (1999, 159) assert, "Recurrent menstruation is unnecessary. . . . It is a needless loss of blood."

Thomas and Ellertson (2000, 923) draw analogies with other conditions now commonly controlled with pharmaceuticals, noting that "modern medicine is all about the artificial control of conditions that range from the life threatening, debilitating, and uncomfortable to matters of mere taste." An apt comparison might be made with aging. As with menstruation, some now see aging as a biological process that is "neither natural nor inevitable" (www.antiagingny.com). Groups like the New York City–based PhysioAge Medical Group purport to "stop" or "slow" the aging process through the use of hormonal replacement therapies (HRT), which had initially been targeted to women for menopause. They believe that they can "correct hormonal imbalances" so as to maintain youth longer and to prevent diseases associated with aging such as osteoporosis, cardiovascular disease, and Alzheimer's.[22] Both hormonal menstrual suppression and anti-aging HRTs illustrate how bodily processes that are considered "undignified" and detrimental to one's sexual appeal are, at least by some, no longer thought to be necessary.

MENSTRUAL SUPPRESSION: AN ENHANCEMENT TECHNOLOGY?

"Enhancement technologies" have been described as those aimed at "improving human characteristics, including appearance and mental or physical functioning, often beyond what is 'normal' or necessary for life and well-being" (Hogle 2005, 695). These new, body-altering techniques repair, replace, and even redesign the human body in response to individual wants (Hogle 2005, 696). Well-known examples include the use of anabolic steroids for athletic performance enhancement, hormones for rejuvenation, and the use of human growth hormone for short children because height is thought to improve an individual's chances for success. These culturally shaped needs and desires reinforce already existing gender norms. For example, drugs are now sometimes being used to limit the height of tall girls who would otherwise exceed the standards of femininity. Are menstrual-suppressing birth control pills performance-enhancing drugs? Do they improve an individual's chances for success, and, if so, how?

Just as with soldiers, truck drivers, and test takers who are being given or self-administering drugs to enhance performance, the demands for productivity in the workplace may be legitimating hormonal menstrual suppression. For example, ob-gyn Shari Brasner explained how she began adapting normal birth control pills to suppress her periods (by skipping the placebo pills) when she "decided that my busy schedule really precluded the ability to take a break to go to the bathroom every couple of hours to take care of personal needs" (Harris and Saul 2006). Adds Linda

C. Andrist, a professor at Massachusetts General Hospital's Institute of Health Professions in Boston, "[W]e don't want to confront our bodily functions anymore. *We're too busy*" (Saul 2007, A1, emphasis added).

Proponents of suppression often highlight the economic consequences of menstruation. For example, Andrew Kaunitz, a gynecologist who was one of the site-testers for Seasonale, notes that "[m]enstrual disorders represent a major cause of absenteeism from work" (Chesler 2006). A Canadian study that found that women afflicted by heavy menstrual bleeding give up $1,692 a year in lost wages (Saul 2007, C4). According to Thomas and Ellertson, "menstrual disorders cost U.S. industry about 8 percent of its total wage bill" (2000, 922). With gendered attitudes about work productivity, women's absenteeism is often interpreted as another example of how women's reproductive processes (menstrual cramps, pregnancy, child care) interfere with the efficiency of the workplace. A number of contributors to the MUM Web site mention how the economic system does not accommodate women's bodily needs. For example, one woman writes, "I don't judge anyone who wishes to stop their menstruation, but I think that modern western existence is fundamentally anti-feminine, and that we are being reshaped into suffering worker drones for capitalism." Another woman writes, "In this world of male corporate culture, where most women work outside the home, it is difficult to take time for oneself as a woman without feeling like a 'whiner' and 'complainer.' "

In addition to its potential for enhancing productivity, menstrual suppression might be considered an enhancement technology along the lines of cosmetic surgeries intended to improve appearance and increase sexual attractiveness, given the fact that taboos against having sex while menstruating appear to still be diminishing women's sex lives.[23] Writing in 1976, Delaney, Lupton, and Toth devote a chapter, entitled " 'Not Tonight, Dear,' " to the subject. They observe, "What is so remarkable about the sex taboos against menstruating women is that they have not faded into vestigial reminders of a primitive past; they are still very much a part of everyday life for most people" (1976, 14).[24]

Submissions to the MUM Web site indicate that the taboo is still a factor for some women. Some don't have sex during their periods either because of their own beliefs or those of their sexual partners, while others do but recognize that others might disapprove.[25] "I would gladly have sex while on my period, as I find it really does tend to lessen cramps, provided my partner wasn't disgusted by the whole affair." Another woman who would like to suppress her periods writes, "I don't like having my husband be so disgusted by my menstrual fluid that he will not have sex with me during that week. That hurts my feelings, and the worst part is it's not his fault. He was raised by women who were disgusted by their own bodies, and through them he was taught to be disgusted." Another confesses she "even ha[s] sex during that time and that always makes me feel better. Disgusting? Well, I don't care. It's not to me and it's not disgusting to my husband. It's just the normal me. You can say what you want but I have the feeling it's a lot more fun the way I do it instead of . . . pushing my husband out of bed." One woman advises, "Have sex if you want to when you're bleeding—men need to get over their fear of blood—it's only your mind holding you back. I have been blessed with men in my life that have no issues with menstruation and sex."[26]

SCHEDULED MENSTRUATION: THE MODERN, YET FEMININE ALTERNATIVE?

One important feature of Seasonale is that it allows women to schedule their periods.

In this regard, menstruating is comparable with other reproductive events that American women are increasingly likely to schedule, including birth (either via scheduled induction or scheduled caesarian sections) and pregnancy loss. Induced labor has become much more common in the United States in the past fifteen years. The rate of inductions doubled, growing from 9.5 percent in 1990 to 20.3 percent in 2003.[27] This trend is seen as "a product of our times" (Fink 2000) that suits "our fast-paced lives" and allows women to exercise their "choice" and ensure that the baby not "arrive at an inconvenient time" (Lane 2006). In this way, Lane reports, families can plan on being home for the holidays, be sure the baby is born when the family is all together (e.g., before the father is shipped to Iraq), and accommodate the "career demands of both parents" (Lane 2006). It also spares women the "discomforts of late pregnancy" (Lane 2006). Similarly, the rate of elective caesareans has increased in the United States. In 2006, 31 percent of births were c-sections, up 50 percent from 1996 (Park 2008). Estimates of how many of these were elected are as high as 18 percent (Park 2008).[28] The growth is attributed in part to a growing number of women who are requesting elective caesarians. The reasons given are for "convenience—the ability to fit childbirth into their work schedules, plan for the care of their other children, or have spouses, parents, or both present at the birth" (Brody 2003).[29] Others prefer it for cosmetic reasons, to avoid the "vaginal stretching and mauling" of natural birth (Hamer 2007a). Anecdotally, there is evidence that because of the tax benefits of having a dependent, the planned induction and c-section rates are highest in December.[30]

Layne (2003, 4) describes having used injections of the hormone progesterone to postpone an imminent miscarriage until after a professional conference, so as not to add a professional loss to her personal one. Although this practice may be rare, many women with diagnosed fetal demise choose to schedule a D&C or induction, depending how far along they are, rather than waiting for "nature to take her course."

The ability to schedule one's periods is being pitched as a sign of modern womanhood. In their book, *Is Menstruation Obsolete?,* Coutinho and Segal argue that menstrual suppression is a distinctly "modern" solution for the problems of modernity (including unnaturally frequent menses), because it is modern life that has led women to deviate from what the authors believe is their "natural" state of continual pregnancies and breast-feeding. Similarly, Dr. Leslie Miller, associate professor of obstetrics and gynecology at the University of Washington, is quoted as saying, "[S]uppression of menstrual cycles is a modern solution to a modern lifestyle" (www.noperiod.com).[31]

On the Seasonale/Seasonique Web site (2007), women are invited to use the "Personal Planner" to schedule "events like vacations, business travel, romantic encounters, and family reunions based on your inactive Pill dates," and a write-up about Seasonale on the Cleveland Clinic's Health Information Center Web site assures, "[O]n a wedding day, honeymoon, or family vacation, for example, no woman wants to have the added burden of menstruation."[32] The examples typify femininity, with honeymoons and weddings also signifying normative, heterosexual sexual activity. The type of woman who is envisioned in Seasonales marketing campaign is young, middle or upper middle class,[33] works outside of the home, is heterosexual, and is a "modern" yet feminine woman. Modernity is invoked as a way to differentiate Seasonale from "traditional" birth control pills. An early advertisement shows women choosing one of a group of items (airport chairs, high-top sneakers, yoga mats) that are colored gray, and selecting the one that is pink. A more recent brochure develops the same trope, using the contrast between black and pink to promote the desirability of this product (Duramed 2005b). An attractive, young, feminine (skirt- and high-heel-wearing) woman is shown walking by a long row of identical black armchairs glancing back over her shoulder at the one pink chair. On the next page she is pictured sitting on the pink chair; that is, having chosen it and made it her own through the deployment of her body. On another double-page spread at the center of the brochure she is pictured looking down, admiring the pretty pink shoes she is wearing that she has clearly chosen out of an endless line of identical black ones. In addition to signaling femininity with pink, Seasonale uses the various versions of this visual metaphor to distinguish itself from boring, old-fashioned, ordinary birth control pills, and at the same time suggests that the consumer can distinguish herself as a young, attractive, feminine, fun-loving woman by choosing this form of birth control. The metaphor can also be read as referring to the way one's period days are different from ordinary days. In this reading, the occasional period is a fun, feminine alternative to ordinary, undifferentiated days. And with Seasonale, the pink days will be even more special because they are more rare and, like the pink shoes, an expression of personal choice. This trope also suggests the ease of use: chairs and shoes are familiar technologies that women already know how to use to accessorize their bodies.

SEASONALE: THE MAINSTREAMING OF AN APPROPRIATED TECHNOLOGY

Seasonale presents an interesting example of "appropriated technology."[34] Birth control pills have long been adapted by users to schedule or eliminate their periods. Users simply skip the placebo pills of their monthly cycle. In their 1976 book, *The Curse: A Cultural History of Menstruation,* Delaney, Lupton, and Toth devote a chapter to various techniques women have used in "escaping the monthlies," among which they single out hormones as "undoubtedly the least unsafe suppressor" (1976, 215). Hormones have been given as menstrual suppressors to "paraplegic and severely handicapped women and to women in plaster casts," used by prostitutes to stop their periods indefinitely, and by athletes to delay a period until after an important athletic competition although women have won "gold medals and established new world records in the . . . Olympics during all phases of the menstrual cycle" (1976, 57). There is no accurate data on how many women are now regularly skipping placebo pills, but medical organizations and reproductive health centers—such as Reproductive Health Technologies Project and Association of Reproductive Health Professionals—acknowledge the practice (Thomas and Ellertson 2000). One contributor to the MUM Web site, a twenty-three-year-old biologist from Malaysia, reports that "dancers, athletes, and other women who find periods inconvenient have known about this trick for a long time" and she recalls an experience from her childhood when they "were going to the beach for a camp with their church and her twelve-year-old sister and her best friend were on their periods" and the friend's father, a gynecologist, "gave them some pills to stop their periods so they could swim." Gottlieb (2002, 388) reports that some Balinese women take birth control pills in order to delay the onset of their periods, "precisely timing the menstrual cycle" so that they can "participate in traditional temple rituals from which menstruating women are still actively banned." She interprets this "cultural conservatism" as being, like the veil, an expression of "ethnic pride and nationalism in the face of international pressure to Westernize" (Gottlieb 2002, 388).

"Appropriated technologies" represent a reversal of the typical power flow in technology design and production from those with high social power to consumers who may be outside the centers of social power, and thus may incline us to be positively predisposed to them. Indeed, we might interpret Seasonale as an example of "the collective force of [women] in shaping technology design through market demands" (Eglash 2004, xvi). But appropriated technologies are not necessarily liberatory. As Eglash (2004, xvii) observes, "[A]ppropriated technologies do not have an inherent ethical advantage. First, insofar as appropriation is a response to marginalization, we should work at obviating the need for it by empowering the marginalized. Second, not all forms of resistance are necessarily beneficial in the long run." Furthermore, Seasonale and the other "me-too" menstrual-suppressing birth control pills coming to market are simply packaging this already-appropriated technology and selling it back to women at inflated prices.

MENSTRUATION = WOMANHOOD?

Underlying much of the discussion surrounding menstrual-suppressing birth control are essentialist claims about femaleness. For example, psychiatrist Dr. Susan Rako, author of *No More Periods? The Risks of Menstrual Suppression* (2003), maintains that these new technologies are "doing away with women's normal hormonal menstrual cycle, which is really responsible for what fundamentally makes a woman a woman" (Cox and Feig 2003).[35] The respondents in Aengst's survey who were reluctant to use Seasonale linked a monthly cycle with femininity. Many of the contributors to the MUM Web site expressed similar views. One thirteen-year-old reports that although she "HATEs period pains" she "always feels blessed when 'it's that time of the month.' I love the feel of being a woman . . . I . . . like that I am growing up and . . . it makes me really happy and proud to be a woman." A thirty-six-year-old woman says she would never give up her period. "I like that it is regular, I love to feel the cramps. It reminds me of being in labor and the power that I found there. The power that resides deep within me, connecting me to all women who have lived before, and all to come." She is teaching her daughters by example that "cramps are part of the power of being a woman." A thirty-two-year-old U.S. mother of three who is a graduate student in Southern California and "would never give up [her] periods" says, "I am the woman I am in a large part because of my relationship with my body—my awareness of my cycle, my knowledge of how my parts work, my connection to my fertility." Another contributor writes, "To suppress menstruation is to suppress being a woman."

A woman from Zambia notes that even though it's inconvenient when traveling, "it's a wonderful experience of womanhood. It makes us different from men." Another writes, "[I]t's what makes us special." Several refer to their periods as "a gift." "You bleed each month because each month you have the potential to create LIFE. Screw being envious of men. We create men! We can make men and women right in our bodies and it is a beautiful and amazing privilege!" Another says, "[O]ur periods are like our trademark," and counsels that others should "be proud to be a woman." A forty-eight-year-old woman explains why she would not choose menstrual suppression: "I feel connected to other women around me and throughout time." A thirteen-year-old says, "I feel like it is a bond with all women, one of my few assurances that I'm normal. It assures me that I am healthy and similar to half of the earth's population."

Many others react to these expressed views. Of women who say that "they didn't feel like women without their periods," one mother replies "Bah!" and shares how much she would welcome "never having to deal with a bloody tampon again." A woman who has menstruated for thirty-five years says that she has "appreciated the feminine, the moon cycles, the fecundity, the fertility. It's awesome, . . . now go away, shoo. I am woman, hear me roar." One woman who reports she "would stop in a heartbeat if [she] could" explains, "I have been a teenager bleeding, a young woman bleeding, and a mother bleeding. Now I'm tired of bleeding. My womanhood has been proven!" A nineteen-year-old with very difficult periods replied, "I love being a woman and I feel empowered because of who I am, but my period does not make me a female. I don't need my period to remind me 'oh yeah, I am female.' " A forty-three-year-old from the United States says, "[T]his doesn't make me feel like a woman. It makes me feel dirty, like hiding all day. I feel like a woman when I can put on a pretty dress, not worry it'll get stained, and be intimate with my husband." Another writes that menstruation does not "prove your femininity. Hell, if I want to get in touch with my feminine side I'll look in my heart and mind, not at the red blood in the toilet."

MENSTRUATION = WOMYN/NATURE?

Many of the arguments against menstrual suppression not only allude to the special bond that menstruating creates among women, but also to the bond it creates between women and nature. One of the respondents to Aengst's survey commented, "I think the monthly cycle represents a powerful connection with the cycles of nature—a reminder that life is constantly in flux and corporeal bodies aren't the same at all times." A contributor to the MUM Web site who self-describes as "a pagan" uses her "blood in rituals" and likes "how it connects me with the earth, especially in our modern world." Another contributor writes, "I almost always get my period right around or after the full moon, . . . and I like that vague connection to the moon/the universe." A twenty-eight-year-old from Alabama states, "[T]here's no way that I would give up my Moon cycle other than for pregnancy or naturally occurring menopause!" A thirty-four-year-old from Virginia writes, "I enjoy the regular reminder of my power as a womyn and of my connection to the moon and the tides." And a woman in her early thirties says that although "at an earlier stage of my life I would have said yes" to suppression, "I learned later in my life that our moon cycle is a gift from the Goddess. . . . In ancient times women were revered and respected because she could bleed without a wound. The blood was given to Mother Earth to nourish her." Another writes, "Menstrual blood has been used to fertilize plant life (I give it to my plants—they love it!)" and one urges other women "to engage with our connection to the planet and stop harmful . . . activities. I wish every woman could observe nature on a daily basis, sit in her garden and tend vegetables, have time to make a simple meal, be able to sit, chat, sew and comfort."

Some object to the views of those who link menstruation with nature/womanhood. For example, one writes, "Those moon-womyn with their raspberry leaf tea just make me tired. Menstruating smells. Get over it. There's an odor and it isn't raspberry tea, sweetheart." Another contributor quips, "I think all these folks going on about their 'Moon Time' are full of it. They have never had a painful period." A more tolerant response is expressed by a woman who states, "I'm happy for women who feel that having their period connects them with the moon and the tides. For me, though, all that my period connects me with is a 500-count bottle of Advil and a heating pad." And a fifty-year-old who gets migraines before her period starts and has gotten her periods "regular as clockwork since I was 12" writes, "I don't need this any more. Mother Nature, lay off already."

IS SEASONALE A FEMINIST TECHNOLOGY?

Different feminist theories render different answers to this question. In this section, we begin by using the "how would this look if it were men" technique to begin our feminism assessment. We then consider the issue through the lenses of liberal, radical, socialist, essentialist/cultural, eco-, African American, existential, and cyborg feminism[36] and conclude with our own evaluations. Readers should keep in mind that we are describing feminist theories and that feminists often embrace more than one of these perspectives.

THE "HOW WOULD THIS LOOK IF IT WERE MEN?" TEST

One technique often used in thinking about whether a technology or social arrangement is feminist (or sexist) is to consider how the issue would look if the sexes were switched. In the case of menstrual-suppressing drugs, perhaps a comparable male case would be a semen- or ejaculation-suppressing drug. This comparison is in fact made by a twenty-six-year-old Portuguese contributor. She writes, "Look at men—do you think they see their sperm as repulsive? Oh, God, no! They tend to be proud of it. They're proud of their sexuality. . . . And do you think a period is more repulsive than sperm? Well, I personally don't think so."[37]

As this woman points out, like menstrual blood, ejaculate could be considered dirty, messy, ritually polluting, and/or inconvenient, and, like menstrual suppression, ejaculate suppression could serve as a method of birth control. Even though several drugs suppress ejaculation (e.g., Flomax, a drug prescribed to men who have enlarged prostates), this is not being marketed as a sales point but as an unwanted side effect.[38]

Liberal Feminism

Liberal feminism has tended to celebrate the expansion of choices for women, including increasing the number of options that women have for birth control. Thus, from a liberal feminist point of view, Seasonale and other menstrual-suppressing birth control pills would likely be embraced as expanding women's choices. Dr. Ruth Murkatz of the Population Council, who believes menstrual-suppression birth control pills provide "another choice for women, so they can control their destiny" and concludes "choice is good" (Chesler 2006), provides an example of this approach.

In addition, since liberal feminists tend to focus on equity, to the extent that menstruation makes it more difficult for women to compete equitably at work or to enjoy vacations and sex as much or as frequently as men, one could argue that, from a liberal feminist perspective, eliminating menstruation would be beneficial.

Radical Feminism

Whereas liberal feminism embraces the notion of expanded "choices" as a benefit in and of itself, radical feminism highlights how the choices offered to women are shaped by patriarchal systems and may in fact harm women. Radical feminists would likely deem Seasonale an antifeminist technology. Rather than suppressing menstruation, a radical feminist approach might be to redesign workplaces, schedules, and expectations to accommodate women's cyclically changing capacities and predilections. This is the position taken in Martin's classic *The Woman in the Body* (1987, 122–25), in which, after discussing the problems for women caused by late industrial society's demand for regimented physical and mental discipline while on the job, she refers to Beng women from the Ivory Coast as an example of a culture that plans on and accommodates a cyclic change in women's usual activities.

Socialist Feminism

This approach is based on the belief that "there is a direct link between class structure and the oppression of women" and that we must therefore challenge both "the ideologies of capitalism and patriarchy." Women must work side by side with men in order to achieve this (Stewart 2003). To the extent that menstrual-suppressing technologies are perceived as tools to render women more willing and able to be subjected to the physical and mental discipline that capitalism requires to maximize productivity and efficiency in the workplace (Martin 1987, 122), socialist feminists are likely to oppose them. Like the contributor to the MUM Web site who perceived a link between menstrual suppression and the way men and women are being "reshaped into suffering worker drones for capitalism," socialist feminists would likely prefer to organize labor in such a way that both men and women would be able to take more paid personal days.

Essentialist Feminism/Cultural Feminism

Essentialist feminism (now known more commonly as cultural feminism)[39] is based on the idea that "there are fundamental, biological differences between men and women, and that women should celebrate these differences. . . . Cultural feminists are usually non-political, instead focusing on individual change and influencing or transforming society through this individual change. They usually advocate separate female counter-cultures as a way to change society but not completely disconnect" (Stewart 2003). An example of this approach is found in a contribution to the MUM Web site from a woman in Chicago who writes, "I love my period. It's my Moontime, my time to relax, pamper myself, and be creative. . . . I listen to female musicians, read female authors, admire female artists, and chat about intimate issues with my female friends. I eat healthier and indulge in the richest, darkest chocolate. I also feel a greater spiritual connection during my Moontime." Through this lens, menstrual-suppressing drugs are not only not feminist, but antifeminist.

Ecofeminism

This approach is premised on a deep link between women and nature, and patriarchy is understood as the simultaneous domination of both nature and women. In ecofeminism, women's special understanding of nature enables them to provide progressive solutions for "how humans can live in harmony with each other and with nature" (Stewart 2003). We saw examples of this in the contributions of those who feel their periods provide a special link to nature. These contributors tended to also embrace an essentialist/cultural perspective. Thus, it seems that from an ecofeminist point of view, like that of the essentialists/culturalists, menstrual suppression is not only not feminist, but antifeminist. However, because with drugs like Seasonale women will no longer be purchasing disposable, one-use only sanitary pads and tampons that end up in landfills (Strasser 1999, 161–70), one might argue that it therefore qualifies as an ecofeminist technology. The counterargument is that there are other technologies that already exist (e.g., reusable cotton pads, menstrual cups).[40] that meet this need without women having to suppress their cycles by making themselves dependent on a consumer product that must continuously be replenished.

African American Feminism

African American feminism focuses on "the promotion of black female empowerment" and is characterized by "the presentation of an alternative social construct for now and the future based on African American women's lived experiences." It is based on the recognition of "multiple systemic forces of oppression" and thus entails "fighting against race and gender inequality" (Barnes 2008, 1).

This perspective has been noticeably absent both in the public debate and in the self-reports on the MUM Web site. (Only one of the contributors self-identifies as black and she is against suppression: "I am a black student doctor of a natural health care approach and a woman. I wouldn't stop menstruating if I had the chance (including after having children)." An African American feminist perspective would be cognizant of the many reproductive rights abuses that have been directed at African American women (as well as other women of color in the United States and globally). The early birth control movement was associated with the eugenics movement, which often singled out black women (Roberts 1997, 70–79). Forced sterilization and the targeting of blacks for new, inadequately tested, extended-regimen hormonal birth control in the form of Norplant and Depo Provera (Nelson 2003; Roberts 1997), suggests that African American feminism would be wary of Seasonale and other "extended-regimen" birth control pills.[41]

Existential Feminism

Existential feminism derives from the work of Simone de Beauvoir. In *The Second Sex* Beauvoir describes the ways women's bodies make them subservient to the demands of the species to procreate in a way that greatly exceeds the demands placed on men. She has a very negative view of menstruation, which she sees as a useless burden "from the point of view of the individual" (1989/1949, 27). She writes: "Menstruation is painful: headaches, over fatigue, abdominal pains, make normal activities distressing or impossible; psychic difficulties often appear: nervous and irritable, a woman may be temporarily in a state of semi-lunacy. . . . The body seem[s] a screen interposed between the woman' and the world . . . stifling her and cutting her off" (1989/1949, 329).[42] She sees the end to menstruation with menopause as the only way that "women escape the iron grasp of the species" (1989/1949, 31).

From this, it seems evident that she would have embraced menstrual-suppressing drugs had they been available. This view is also supported in her general stance vis-à-vis nature. She celebrates human society that exerts mastery over nature. "Human society is an antiphysis—in a sense it is against nature; it does not passively submit to the presence of nature but rather takes over the control of nature on its own behalf" (1989/1949, 53). She has a generally positive attitude toward technology because of the potential to equalize men and women's physical abilities.[43]

However, other elements of *The Second Sex* suggest that she had some positive attitudes toward women's reproductive biology, linking ovarian function to women's vitality (1989/1949, 27). But although she recognized the body as "one of the essential elements in her situation in the world," Beauvoir asserted "that body is not enough to define her as woman" (1989/1949, 87). Instead, Beauvoir privileges individual consciousness manifested through activities. Women's second-class status is a result of broader social traditions. She uses pregnancy as an example to illustrate the way the same biologic phenomenon differs depending on social arrangements. The burdens of maternity in societies where women do not have reproductive freedom and little social support "are crushing," whereas in societies where "she procreates voluntarily" and "society comes to her aid . . . the burdens of maternity are light and can be easily offset by suitable adjustments in working conditions" (1989/1949, 54). Thus, we might infer from this that she might favor similar social accommodations rather than drugs to alter women's biology.

Finally, Beauvoir urged women to "confront internalized desires that lead to acceptance, and thus perpetuation, of society's conventional definitions and expectations of femininity" (Marso 2006, 17). Hence, existential feminists might object to menstrual suppression as an unthinking compliance with conventional definitions of femininity; for example, the ability to wear a "pretty dress" without worry of staining. Furthermore, given Beauvoir's emphasis on individual intellectual and creative actualization, one would expect her to celebrate the achievements of women like this contributor to the MUM Web site who reports enjoying her greatest productivity during her menses. "I am an artist and a feminist article writer and I come up with my most powerful, eloquent, meaningful pieces during my Moontime."

Cyborg Feminism

According to Donna Haraway, the person most closely associated with cyborg feminism, the separation of nature and culture has been particularly detrimental to women (Haraway 1991). Cyborg feminists believe that disrupting the nature/culture duality will not only free us from the constraints of essentialism but will also allow us to conceive of and employ science and technology to further women's aims in a more nuanced manner. The cyborg—a heterogenous mix of human and machine—moves beyond binaries and essentialism. Among cyborgs, it becomes more difficult to distinguish dualistic categories such as "nature" and "culture." A cyborg feminist position poses unsettling (yet also liberating) questions: what counts as "nature"? What counts as a "woman"? The ambiguity, in Haraway s view, is liberating. Hence, a technology like Seasonale, which compels us to confront our cultural ideas of "normalcy? "nature," and "necessity," can be considered feminist for this reason. Haraway's cyborg is a compelling image because it reveals the arbitrariness, and thus instability, of our categorizations.

TWO SOCIALLY/MATERIALLY SITUATED CONCLUSIONS

Given that whether or not a person considers menstrual-suppressing birth control pills to be a feminist technology appears to be shaped both by one's personal experience with menstruation and the type of feminism(s) she or he embraces, it is not surprising that we (Layne and Aengst) differ in our assessment of this issue. We provide two alternative sets of conclusions as well as points of convergence.

Layne: I am a perimenopausal woman who has experienced regular, unremarkable menses for thirty-seven years or so. For the vast majority of my adult life I have used a diaphragm and contraceptive jelly for birth control, a method that I have found effective, safe, and easy to use, and one that has the added benefit of containing menses. I am pleased there are a growing number of ways to alleviate the suffering of women with "menstrual disorders." Given that two of the most of common therapies (hysterectomy and uterine ablation) preclude future child bearing, alternatives are clearly needed. But even for women with menstrual disorders, I am reluctant to deem menstrual-suppressing drugs as feminist technologies because the recent invention of the Vipon, a vibrating tampon that appears to relieve the menstrual pain of women with endometriosis (Vostral, this volume), alerts us to the fact that even if menstrual-suppressing birth control pills are the best option for women with menstrual disorders now, there is no reason to think that there are not better alternatives that have not yet been created by feminist designers.[44]

As for the use of menstrual-suppressing drugs to suppress "normal" menses (being cognizant, of course, of how both the notions of "normal/abnormal" are culturally shaped), as a radical feminist, I am opposed. Rather than women using technologies to alter themselves to more comfortably fit the demands of a patriarchally shaped world, I would prefer to reshape the world to better accommodate women. Furthermore, as a medical anthropologist working in the era of "big pharma" (Angell 2005), I am oriented against the expansion of drug regimens, and prefer mechanical (mostly reusable) menstrual-management technologies like menstrual cups (see illustration), diaphragms, reusable cloth pads (Vostral, this volume), or even menstrual extraction. Menstrual extraction is a technique developed by a group of feminists in Los Angeles at the Self-Help Clinic of the Feminist Women's Health Center, in which a woman or a friend inserts a thin tube into her uterus when her period begins, and uses a syringe to suction out the endometrial lining, a procedure that takes only minutes (Delaney, Lupton, and Toth 1976, 215–16). Delaney, Lupton, and Toth deemed menstrual extraction as "by far the most exciting discovery of the women's health movement" because it provides "newfound control over our own bodies" (1976, 217). This is a safer, less expensive, and more self-controlled alternative than daily drug use for those who wish to be spared the task of managing their menstrual cycles more conventionally. This technique has the added benefit of enabling early abortion, should that be desired.

A final consideration for me of the feminist/antifeminist valence of menstrual-suppressing drugs stems from the fact that these pills have been so newsworthy. Part of the reason these drugs make such good news copy is that women are so sharply divided on the subject. As we have seen from the contributions to the MUM Web site, not only do women differ physically (in their experience of menstruation) and attitudinally about the value/meaning of menstruation, they also are sometimes highly judgmental of those who differ from them. Could it be that this subject is so mediagenic precisely because of its catfight potential? The tampon, the home pregnancy test, and the breast pump have not generated such heated divisions between women, nor have they been the subject of comparable media attention. I suggest that the valence of a technology, either to pit women against each other or bring them into solidarity, might be added to the list of criteria that qualify/disqualify technologies as feminist. Note, I am not suggesting that there should be a single feminism or that women could or should see things the same way. The diversity of the feminist movement is what makes it such "a many splendor'd thing" (Meyer 1987, 389) and this diversity will be an important resource for the proliferation of feminist technologies.

Aengst: I first became interested in Seasonale when my gynecologist told me that she could make my periods disappear. "Women don't have to have a period anymore," she said to me, "nowadays, there are just so many more options." I left the office disturbed by her comments, which seemed to be a bit too cavalier, although I was equally intrigued by the thought of having more reproductive health options. I realized that my own misgivings about taking long-term birth control pills was bound up in the fear of a new technology, essentialist ideas about gender, and fairly ingrained ideas about what was "natural." After much consideration, I am still uncomfortable with Seasonale and have no desire to use menstrual-suppressing drugs. Because I have been a regular user of "traditional" birth control pills for many years, Seasonale is appealing in its similarity to the pill regimen I am already taking. Yet, as someone who spent much of my adolescence wishing my periods were more regular, I find the idea of going many months without a period disturbing. Despite being aware of how the notion of "natural" is socially and culturally constructed, I find myself still preferring to have a monthly, more regular period.

Although I like that Seasonale disrupts notions of biological female essentialism, it leaves essentialist ideas about men uncontested.[45] In addition, this technology maintains the well-entrenched belief that women are the ones ultimately responsible for birth control. The development, distribution, and use of male methods of birth control is long overdue. Male-oriented birth control methods will not only disrupt gendered notions of female and male essentialism but will also challenge the idea that contraception is solely a "women's issue."

Furthermore, there are underlying class and sexist and racist ideologies related to menstrual suppression. Seasonale is an expensive technology that remains inaccessible to lower-income women and to those within the developing world. Many theorists have pointed out how cultural norms—such as determinations of who takes birth control pills and what methods are deemed "appropriate" for women in the developing world—influence those in the policy and development world, which ultimately determines where reproductive technologies travel (Sen, Germain, and Chen 1994). Unfortunately, because the development and policy literature often suggests that women in the developing world cannot be trusted to reliably take a daily pill, and because of the expense, menstrual-suppressing birth control pills are less likely to be available for women in the developing world.

Seasonale might very well be a useful technology for middle- and upper-class women who seek convenience and can afford to choose among many contraceptive technologies. Disrupting deeply entrenched norms of "nature" and "necessity" is a great step—and this is what makes Seasonale a worthwhile technological development—but it has not gone far enough.

CONCLUSIONS

Seasonale proves to be an excellent test case for honing the definition of feminist technology and for modeling a feminist technology assessment. As we have seen, menstrual suppression raises to the forefront differences among women—physical, social, cultural, and attitudinal. It also highlights differences within feminism. It is by struggling to take into account these differences that we can make headway in defining, recognizing, calling for, and creating feminist technologies.

NOTES

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1. Seasonale is a trademark of Duramed Pharmaceuticals, Inc.
2. Their actual effectiveness is estimated to be only 92 percent, with 8 of 100 women on the pill getting pregnant each year. According to Gawande (2007), "[W]ith lower dose hormone formulations," like Seasonale, "missing a dose by even six hours puts a woman at" such risk he advises the use of condoms for that whole month.
3. These and other risks are discussed in detail in the six-page, small-print, black-and-white product insert.
4. This marketing slogan is trademarked by Barr Laboratories, of which Duramed is a subsidiary.
5. This is a classic case of the proliferation of what are known as "me-too" drugs, new products that "are no better than drugs already on the market to treat the same condition" (Angell 2005, 75). According to Angeli (2005, 75), 77 percent of all new drugs approved by the FDA between 1998 and 2002 were "me-too" drugs. According to their Web site, www.shortperiod.com, "Loestrin 24 Fe uses the lowest dose of estrogen (20 mcg per pill) currently approved by the FDA for effective birth control."
6. Other hormonal contraceptive methods can also suppress menstruation. The contraceptive cervical ring, NuvaRing, is being used by some to suppress menstruation (Associated Press 2006a), and Implanon, a birth control rod implanted into the upper arm that works for three years "stops menstruation in many women." A feminist comedic video on menstrual-suppressing forms of birth control can be seen at http://www.feministing.com/archives/010078.html.
7. Respondents are encouraged to tell their age and where they are from.
8. Aengst asked sixty women on her e-mail list (who are white, middle-class, educated women, ages twenty-five to forty) whether they have ever taken birth control pills, whether or not they would take Seasonale, and why. Of the nineteen women who responded, eighteen had taken birth control pills; however, only four said they would take Seasonale. The two main reasons they gave for this was because they liked the monthly reassurance that they were not pregnant and they felt that taking Seasonale would disrupt the "natural" monthly cycle. In contrast, a much higher proportion of the 919 respondents to the question posed on the MUM Web site said they would suppress: 545 said they would, 374 said they would not. Women who post on the MUM Web site may be more likely to experience menstruation as problematic and have discovered the Web site while searching the web for help and support.
9. These physical differences include endometriosis, blood disorders, and mental (Thomas and Ellertson 2000, 922) or physical (Colligan 1994) disabilities that make managing menstruation particularly difficult.
10. See for comparison Hardon's discussion of the role of the Population Council in the development and testing of two other long-acting contraceptives, Norplant and antifertility vaccines, and the women's health movement's response (this volume).
11. Coutinho reports that his work with Depo Provera showed that "women who suffered from premenstrual tension and other menstrual disorders welcomed the long menstruation-free intervals." He moves directly from these particular women to generalize about "women"—"it was clear, that, contrary to conventional wisdom, women not only accepted the idea of not menstruating, they appreciated it as a benefit of the treatment" (1999, 10). Later, however, he reports on a ten-country study of menstruation conducted by the World Health Organization in 1983, which found that the majority of respondents of all cultures related some physical discomfort and some mood changes linked to menstruation. Yet in what he sees as a "paradox," given "the many negative aspects of menstruation, . . . the majority . . . did not wish to use a contraceptive method that would suppress menstruation" (1999, 12).
12. They acknowledge their debt to Coutinho and Segal for their "ideas and suggestions imparted over many years" (Thomas and Ellertson 2000, 924).
13. Thomas and Ellertson (2000, 922) also draw on feminist rhetoric in questioning why "no other disease or condition that affects so many people on such a regular basis with consequences, at both the individual and societal level, is not

prioritized in some way by health professionals or policy makers."

14. See Solinger (2001) on how "the language of choice" has come to replace "the language of rights" and how decisions about women's reproduction came to be cast in terms of "the individualistic, marketplace term 'choice.' "
15. According to Johnston-Robledo et al. 2006, 359), the first opponents (i.e., those whose views appeared in the popular press between 2000 and 2003) focused on safety issues rather than sociocultural or psychological concerns.
16. In 2006, Seasonales sales reached $120 million (for the twelve months ending in June). A generic equivalent produced by Watson has since entered the market. Seasonale and Seasonique make up only 0.9 percent of the $1.7 billion annual US. market for oral contraceptives (Saul 2007, C4).
17. It is worth noting that there was comparable concern about the adoption by teens of tampons as a new menstrual-managing technology when they were introduced (Vostral, this volume).
18. In Turkey, when patients resist using hormone-replacement therapy (HRT) for menopause because they see HRT as "unnatural," some doctors argue "not everything natural is a good thing," such as floods and earthquakes (Erol 2008, 134).
19. This is a skillful and unconventional use of an enthymeme to persuade readers that it goes without saying that menstrual suppression is the preferred choice, but that we should be tolerant of those who make other, less enlightened, personal choices like choosing to continue menstruating.
20. It is worth noting that not all "natural," "real" periods involve ovulation. According to Weideger (1977, 6), "The majority of adolescents and the majority of women approaching menopause have cycles in which there is no ovulation, while most women in the 20–40 age group have menstruation without ovulation only once or twice a year."
21. An interesting comparison might be made with HRT for menopause. In Turkey, doctors respond to women who are reluctant to take HRT because hormones are "artificial" with a number of strategies, including arguing that "the estrogen that a menopausal woman takes [is a] part of nature. Like an apple tree presents the substance it takes from the earth to us as an apple and an apple is part of nature; the drugs that people make in the factories by substances they take from nature are the fruits of humans, so a piece of nature" (Kadayifci 2006, 37, quoted in Erol 2008, 134).
22. The Life Extension Institute of Palm Springs also offers anti-aging individualized regimens of "Total Hormone Replacement Therapy" that "may include injections of testosterone and human growth hormone, topically applied testosterone gel, tablets of melatonin and as many as six other hormones that are supposed to slow the aging process and intensify the patient's sense of well-being and sexual vigor" (Hoberman 2005, 13).
23. Again, HRT provides a fruitful comparison. According to radical feminists Germaine Greer and Sandra Coney, HRT is an attempt by patriarchal medicine to "keep women young and 'contributing,' if not to the continuation of the species, at least to the pleasure of men (both sexually and temperamentally" (Roberts 2002, 39).
24. They describe religious prohibitions in the Koran and the Old Testament, and cite a 1973 study by Karen Page that found the prohibition much more frequently observed by Catholic and Jewish women than by Protestants. They also cite a study of black, medically indigent women in Georgia among whom the taboo was "overwhelmingly observed" (1976, 22). In addition to religion, other explanations for the taboo include beliefs that it is bad for men's health, for women's health, for the health of the unborn, and that women are not aroused during their periods. They also mention the case of a woman who had an elective hysterectomy "so that she [wouldn't] have to say no to her husband at that time" (1976, 23). According to Coutinho and Segal (1999, 12), the majority of women respondents in the WHO 1983 survey from all ten of the countries in the study (Egypt, India, Indonesia, Jamaica, Mexico, Pakistan, the Philippines, Korea, United Kingdom, and Yugoslavia) "believed that sexual intercourse should be avoided during menstruation."
25. Sometimes these prohibitions are religious. For example, according to Jewish law, a man may not have sexual relations with his wife during menstruation nor for the seven days following her bleeding, and even then not until she has performed the ritual purifying bath, a mikvah (Alexander 2003). Menstruation is also considered ritually polluting in Islam.
26. Several studies have found that men report more negative attitudes toward menstruation than women (Johnston-Robledo et al. 2006, 354), and one author suggests that "as members of a culture that sexualizes or objectifies their bodies, [women] are motivated to distance themselves or dissociate from bodily functions such as menstruation that are deemed

incompatible with their sexual attractiveness or desirability." Women who reported higher levels of self-objectification had more negative attitudes toward menstruation (Johnston-Robledo et al. 2006, 354).

27. England reached this rate, one out of every five pregnancies, in 1997 (Edozien 1999).
28. About 10–15 percent are emergency c-sections.
29. The rate for caesarian births for first pregnancies increased to 29.2 percent, an increase of more than 40 percent since 1996 (Bakalar 2005). A similar trend is seen in Australia where the c-section rate has risen from about 5 percent in the 1970s to 19 percent in 1994, 27 percent in 2002, and 28.5 percent in 2003 (Hamer 2007a). Of these it is estimated that 5–10 percent are scheduled at a woman's request (Hamer 2007b, 11).
30. Interestingly, Brazil, where Seasonale was developed, has particularly high rates, with some hospitals reporting 80 percent of babies delivered this way (Park 2008).
31. It is not just users who are invited to assert their modernity by choosing this drug, but physicians too. Coutinho and Segal (1999, 163) castigate those who subscribe to "the traditional paradigm, ordained by Hippocrates in an era of medical naiveté, that regular menstruation is good for women." Thomas and Ellertson (2000, 922) link the belief that monthly menstruation is healthy to the outdated and "universally harmful medical practice" of therapeutic, induced "bleeding" of "previous centuries." Similar arguments are made by Turkish doctors in the face of resistance to HRT. The doctor of one woman who explained that she wanted to stop HRT because "her grandmother or her mother never took anything and they were fine" replied that they also rode in ox-carts instead of taking the plane (Erol 2008, 134).
32. http://www.clevelanddinic.org/health/health-info/docs/32oo/3296.asp?index=11283.
33. The woman who goes on family vacations, attends yoga classes, travels for business, and can choose fun, distinctive shoes from ample consumer choices is the woman who can afford Seasonale.
34. Of the three types of appropriation delineated by Eglash (2004:x–xii), this represents an example of "adaptation," which involves a change in use but not structure, and also illustrates the collective force of consumers in shaping technology design through marked demands". (Eglash 2004:xvi).
35. noperiod.com and Cox, Amy and Christy Feig (September 8, 2003) "New Birth Control to Limit Women's Periods" CNN.
36. Rosser (2006) provided a model for this section.
37. The same contributor writes, "I never would have thought that in the 21st-century, women would feel this way about their own body!" She makes a distinction for women who have very painful periods, and those who complain that "it smells" or that it's "disgusting," " . . . having my period doesn't make me dirty or repulsive. It's not disgusting. Do you say blood is disgusting when you cut yourself? I don't think so. You may even automatically lick it when it's a little scratch or something like that (please don't shoot me! I'm not telling we should do the same with the period). But period should be disgusting because it comes out of your sex? This way of thinking . . . shows how much women don't really love or accept themselves. They consider their body beautiful as long as it's attractive to the opposite sex: how nice it is to have big tits nowadays (even if it means back pains or problems, even if it has to be achieved through surgery and looks completely fake and unnatural)! Guys love it. But how disgusting it is having your period: it's not attractive to men . . . "Why can't we women be proud of what we are, no matter if it is pleasant to men or not."
38. According to Georges (2009:100) in Greece menstrual blood and semen are considered similar but in both cases, the discharge of these bodily fluids is understood to rid men's and women's bodies of accumulated impurities (of male and female dirt) and the regular expulsion of both are considered essential for health.
39. Probably as the result of what Fuss (1989:1) describes as "paranoia around the perceived threat of essentialism."
40. The Lunapads website argues, "Like recycling bottles and newspapers, washing Lunapads or rinsing out the DivaCup is a little more work than throwing away your used pads and tampons. But with over 14 billion pads, tampons and applicators going into North American landfills every year, it's a small but important way of taking personal responsibility for a massive environmental problem." www.lunapads.com.
41. The same may be true for other methods of menstrual suppression such as hysterectomies. Whereas black women have too often been urged or coerced into having hysterectomies, contributors to the MUM Web site, who are presumed white unless they mention their race or ethnicity, complain about their difficulties in obtaining surgical menstrual-suppression. For instance, a self-reportedly healthy woman who has never had bad cramps just heavy bleeding writes, "I'm interested in other forms of suppression since

they refuse to give me an elective hysterectomy. Nor will they offer me endometrial ablation . . . would love something permanent . . . I even asked the vet if I could be spayed along with the cat. He just laughed. He thought I was kidding." Similarly, a 43-year-old reports "from home due to missing yet another day from work because of my periods," of her inability to get elective surgical suppression. "I had my tubes tied 11 years ago, and the doctor at that time refused to do a hysterectomy or oophorectomy [removal of the ovaries] to stop my periods, saying I was "too young." Another woman, a stripper who laments the trouble her periods cause her at work has been denied a hysterectomy. "I have to work very hard to conceal my period. The club where I work will not give you time off for your period so here I am trying to find ways to conceal my period while dancing nearly nude . . . most gyno's won't even consider giving me a hysterectomy since "I have nothing wrong." I tried the Norplant, Depo, and now the Seasonale pill. I still have my period on all those things." One woman who did get a hysterectomy explains how happy she was to do so, "I did [stop menstruating]! I have had horrible periods for years, so much so that I missed many professional and personal obligations because of them and they became near-constant and incapacitating. Happily, last week, at age 37 I had a hysterectomy. No qualms about it really and glad to be done with the whole thing."

Others report having used Depo or Norplant, both of which suppress menstruation. For example, a 40 year old who looks forward to menopause reports how much she "enjoy[ed] the year and a half that I was using Depo Provera for birth control. I didn't have a period for nearly two years. It was AWESOME!!!!!!" Others report having tried them but needing to stop because of side effects.

42. She reports that "almost all women—more than eighty-five percent—show more or less distressing symptoms during the menstrual period" (1989:28–29).
43. This strand of her thinking was taken up and developed by Shulamith Firestone, one of Beauvoir's most well-known heirs, in The Dialectic of Sex, which she dedicated to Beauvoir. Firestone (1972:8) writes, women "throughout history before the advent of birth control were at the continual mercy of their biology—menstruation, menopause, and 'female ills,' . . . all of which made them dependent on males." In her view, "it was nature, then, not history, that underlay the inequality between the sexes" (Meyer 1987:396). Firestone (1972:10) asserted, "the 'natural' is not necessarily a 'human' value. Humanity has begun to outgrow nature." Technology, she believed, provided the means for women's liberation from their biology. Hence, menstrual suppressing drugs that help women "outgrow nature" and "liberate them from their biology," would thus be supported by this strand of existential feminism.
44. As always, technologies that would address cause rather than symptoms would be preferable.
45. According to Oudshoorn, "only about 17 percent of contraceptive users rely on so-called male methods."

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CHAPTER 12

Hardwired for Sexism? Approaches to Sex/Gender in Neuroscience

Rebecca M. Jordan-Young and Raffaella I. Rumiati

INTRODUCTION

Gender theorists and some feminist scientists approach gender as a multilevel and complex structure that shapes human relations and perceptions, cognition, and institutions, including the research questions and methods used in science (Fausto-Sterling 2000b; Risman 2004; Ridgeway 2009). Neuroscientists, on the other hand, typically approach gender as a status or a collection of characteristics that male versus female people (and sometimes other animals) have, and the goal of many neuroscience studies is to add to an ever-growing catalogue of male/female differences—both what they are, and how they arise (e.g. Hines 2004: vii). Disagreements over the nature of gender are unlikely to be resolved anytime soon, but we suggest that whether understood as a cultural frame or as an individual cognitive structure, gender is so powerful that it is difficult to get a useful purchase on how it operates. It is a bit like the sun: there is a limit to what we can learn by looking straight at it, and we might just go blind trying. Thus, we argue that a more sophisticated and ethical approach to understanding sex/gender in the brain and behavior will require the somewhat paradoxical strategy of turning away from sex/gender differences in our research.

We use the composite term 'sex/gender,' which will be unfamiliar and perhaps even jarring to some readers, especially those who have worked hard to ensure that complex social phenomena related to masculinity and femininity (gender) are not simply reduced to or confused with aspects of the physical body that can be designated as 'male' or 'female' (sex). We nonetheless favor this composite term when discussing neuroscientific investigations into male/female differences or similarities in patterns of brain structure or function. While conceptual differences between the two are important, 'sex' and 'gender' are, in practical terms, inseparable. Numerous empirical studies demonstrate the problematic task of distinguishing between sex and gender in practice (Oudshoorn 1994; Kessler 1998; Fausto-Sterling 2005; Kaiser et al. 2007). The patterning of life experiences according to social structures of gender has material effects on the body (Willis et al. 2001; Fausto-Sterling 2005, 2008). These effects show up, in turn, as biologically based 'sex differences.' Feminist epidemiologists, biologists, and other scientists increasingly replace the discrete concepts of 'sex' and 'gender' with more complex formulations, such as Nancy Krieger's notions of "biologic expressions of gender" and "gendered expressions of biology" (Krieger 2003).

Thus, we adopt the term 'sex/gender' as suggested by Kaiser and colleagues, who observed that "sex is not a pure bodily and material fact, but is deeply interwoven with social and cultural constructions of gender" (Kaiser et al. 2009: 49). With this composite term, we hope to underscore the importance of problematizing bodily as well as behavioral and psychological attributions of female/feminine and male/masculine.

Next, we address the dominant paradigm of sex/gender differences in contemporary neuroscience. This consists of a broad consensus that there are important 'original' sex differences in brain structure and function, organized by sex-differentiating prenatal hormone exposures (the 'hardwiring' paradigm). This paradigm shapes the work of both those who frame sex/gender differences as sweeping and largely independent of socialization, as well as those who emphasize the role of gender socialization in amplifying male/female distinctions (Baron-Cohen 2003; Eliot 2009). But we argue that this consensus is both unscientific and far from politically neutral. Evidence has long suggested that 'hardwiring' is a poor metaphor for brain development. But the metaphor may be an apt one for the dominant research paradigm, which pushes inexorably towards the 'discovery' of sex/gender differences, and makes contemporary gender structures appear to be natural and inevitable. Finally, we begin to elaborate an alternative research program. While the question of origins can't be studied experimentally in humans, it is possible to design experiments to address questions of variability and plasticity, an approach that we argue has much greater promise from both scientific and ethical perspectives.

Before proceeding further, it is worth addressing how sexuality, the realm of erotic desires and practices, fits with sex and gender. Ideas about sexuality—including but going beyond sexual orientation—play a major role in dominant ideas about sex/gender differences. In science as in popular culture, sex, gender, and sexuality are frequently merged into the simple composite 'sex': a package deal, with both the origin and the ultimate purpose being reproduction. (Note that research has repeatedly demonstrated that heterosexuals in the contemporary U.S. context interpret 'having sex' to be synonymous with penile-vaginal intercourse (Sanders and Reinisch 1999; Bogart et al. 2000).) In this framework, if one part of the 'package' is atypical, it is frequently assumed that the other parts will also be atypical. Moreover, since sex is conceived as a binary, male/female phenomenon, being 'not typical for males' is generally read as being feminine, and being 'not typical for females' is read as masculine. Since the late nineteenth century, same-sex desires have been viewed through this lens, and homosexuals of both sexes have been understood to be intermediate sexual types, whose 'cross-sex' desires are grounded in some kind of 'cross-sex' physicality—most often the brain or the hormones (Kenen 1997; Steakley 1997; Terry 1999). Brain organization research builds upon this way of conceptualizing sex, and uses these presumed links between (bodily) sex, (behavioral and psychological) gender, and sexuality to construct research hypotheses. We do not endorse this 'package' view of sex, gender, and sexuality, but it is necessary to grasp it in order to understand the logic of brain organization research hypotheses that we describe below.

THE 'HARDWIRED' PARADIGM

Scientific Shortcomings

At present, neuroscientific research on sex/gender in humans has stalled on sterile approaches encouraged by the dominant brain organization paradigm, which holds that steroid hormones at a critical period of fetal development give rise to permanent structural and functional sex/gender differences in the brain and behavior (Hines 2004; Cahill 2006; Bao and Swaab 2010). The paradigm, known colloquially as 'hardwiring,' has moved beyond the level of theory to be treated as a simple fact of human development (Jordan-Young 2010).

And yet there are many compelling reasons to reject this 'fact,' beginning with flaws in the developmental model that draw incorrect parallels between genitals and other reproductive structures, on the one hand, and the brain, on the other. According to the classic paradigm of Alfred Jost (1953), a minimum level of androgens—specifically testosterone—is necessary to direct development away from the default 'female' pathway to develop the male phenotype. In 1959, William Young and his colleagues applied Jost's model to brain development (Phoenix et al. 1959). They differentiated between the initial 'organizing' effect of hormones, which are understood to permanently determine the character of the brain and behavior as masculine or feminine, and the 'activating' effects, which essentially determine the level of later activity or expression. Multiple discontinuities suggest that this initially promising extension of Jost's paradigm to the brain is greatly limited. The brain is far less dimorphic than genitals in virtually all species studied, and behavior even less so (van den Wijngaard 1997; Bishop and Wahlsten 1997; Schum and Wynne-Edwards 2005). Moreover, behaviors that are reliably sex-differentiated in some species are not sex-differentiated in others, even in closely related species (e.g. spatial ability (Costanzo et al. 2009), tendency to monogamy vs. polygamy (Lim et al. 2005), and parenting behavior (Lonstein 2002). Genitals—at least in most vertebrates—do have a developmental moment at which an irreversible commitment to a male or female form takes place, while data on brain development indicate far longer developmental periods and extraordinary plasticity, raising doubts about the usefulness of the organization/activation distinction (Balaban 2006). There is also far less continuity across species in terms of the specific relationships between steroid hormones and neuro-behavioral development or function than between steroids and genital development (Resko and Roselli 1997; Tilbrook et al. 2000; Bester-Meredith and Marler 2001; Sheng, Kawano et al. 2004).

The hardwiring paradigm seems to offer an answer to the common question of how it is that widespread sex/gender differences in the brain and behavior arise. Yet that question already presupposes that sex/gender differences are in fact pronounced and wide-ranging, while the reality is quite a bit more complex. In spite of the much-trumpeted 'female brain' and 'male brain,' the brain simply cannot be 'sexed' as genitals can. Imagine that one were to take scientific photographs of the genitals of 1000 human adults, and present these photos to a team of judges without any other contextual cues as to the sex/gender of the individual to whom the genitals belong. Even if our judges were ordinary people with no special training or insights, it would be possible to sort the photographs into 'male' versus 'female' piles with almost 100 percent accuracy. This is not to suggest that there is no intra-sex variety in genital size and shape, but in a group of only 1000 people, it will be possible to clearly place almost all human genitals into one of two main types. Human brains are another matter entirely. Consider first the issue of brain structure. Some scientists claim that there are no clear-cut structural differences, others claim that there are some subtle average differences, and still others claim that sex/gender differences in the brain are dramatic (Fausto-Sterling 2000b; Nopoulos et al. 2000; Canill 2006). When important covariates such as brain weight are controlled, and the specific meaning of 'difference' is not glossed in a way that equates aspects such as cell number and regional volume, the only structural difference that has been independently replicated is in INAH-3, a tiny cell group in the hypothalamus that is larger in men than in women (Allen et al. 1989; LeVay 1991; Byne et al. 2000, 2001). The situation is even murkier when we add the question of function. While we may speculate that INAH-3 may be related to some aspect of sexual function, no one really knows what the area does—it may be elated to something as mundane and 'non-psychological' as menstruation or erectile function.

All indications are that human brains are not 'sex dimorphic'—they do not occur in two distinct forms. There may indeed be differences in the *average size* of specific regions between men's and women's brains (Goldstein et al. 2001), and many activation studies suggest that there are average differences in the way that men and women 'recruit' different regions of the brain when performing emotional and cognitive tasks (see review in Cahill 2006). In fact, with new methods for measuring small regions in living brains, and statistical approaches that allow the detection of increasingly subtle differences between groups, it seems likely that more such average differences will be reported. But these differences are unlike genital differences in two key ways: (1) they are perceptible only at the group level, rather than being distinct forms that can be identified in individuals; and (2) there is no reason to assume that these differences do not arise, at least in part, from gendered patterns of social roles and behaviors—that is, brain differences may *result* from the very characteristics that are supposedly 'hardwired' into the brain in the first place. The point is not that there are 'no sex differences' in the brain, but instead is that the analogy from genitals to brains is extremely misleading.

Another misleading aspect of the hardwiring paradigm is the way it is fueled by systematically omitting evidence that the behavioral patterns that follow early hormone exposures can and do change. As early as 1969, it was known that many of the 'organizing' effects of hormones are not actually permanent, but are easily modifiable by experience. In a little-cited study by researchers at UCLA, for example, scientists found that allowing an androgenized female rat to have just two hours to adapt to a stud male *completely eliminated* the behavioral effects of prenatal testosterone injections (Clemens, Hiroi, and Gorski 1969). Subsequent experiments have shown a great many of the sex-typed behaviors that are supposedly permanently organized by prenatal hormones can be dramatically modified or even reversed by simple and relatively short-term behavioral interventions such as neonatal handling (Wakshlak and Weinstock 1990), early exposure to pups (in rats) (Leboucher 1989), and sexual experience (Hendricks, Lehman, and Oswalt 1982), to cite just a few examples.

There are two sorts of evidence available to indicate that sexed/gendered traits presumably organized by early hormones in humans are likewise impermanent. The first sort involves group-level data indicating both variability and change in the shape of sex/gender differences in cognitive abilities, occupational interests, educational interests and attainment, and even sexual orientation (Smith 1995; Huang et al. 2000; Jorm et al. 2003; Buchmann and DiPrete 2006; Hyde et al. 2008; Hyde and Mertz 2009; National Center for Education Statistics 2009). Although indirect, such data bear on the notion of 'permanent' sex/gender differences by undermining the clarity of the classification of traits themselves as masculine or feminine. Put simply, it is difficult to see how early hormones could direct the brain toward masculine or feminine cognitive or affective phenotypes, when the masculinity or femininity of the phenotypes in question is a moving target. The second sort is recent data on individual-level capacity for change in supposedly permanent traits, even in adulthood. Particularly dramatic evidence involves the most reliably observed sex/gender difference in cognitive skill: mental rotation ability, which consistently favors males (Hyde 2005). For instance, in a study conducted among women and men college undergraduates, Feng, Spence, and Pratt (2007) found that just 10 hours of training on an action video game virtually eliminated the sex/gender difference in spatial attention and simultaneously decreased the sex/gender disparity in mental rotation ability, a higher-level process in spatial cognition, with women benefiting more than men. In contrast, control participants who played a non-action game showed no improvement.

Finally, the idea that the human brain is 'hardwired' for sex/gender can never be settled by experiments. Scientists simply cannot randomly assign human fetuses to different hormone exposures in order to determine how these affect subsequent structure and function. Instead, we must rely on various quasi-experimental designs that search for correlations between sex/gender-linked behaviors, on the one hand, and indications of early steroid hormone exposures, on the other. But evaluating quasi-experiments requires a different approach than evaluating experiments. Because we cannot control the variables, we have to do a very careful and comprehensive appraisal that places all the evidence from multiple study designs into the same picture. Different designs have different strengths and weaknesses, so it is critical to avoid piecemeal evaluation of the multiple research streams, determining whether they 'add up' to some overall positive findings, on balance (Jordan-Young 2010).

In the following paragraphs we briefly review evidence that the dominant paradigm is not well-supported empirically, which has been much more fully addressed elsewhere (Jordan-Young 2010). Here, we focus on the lack of data triangulation across study types. Brain organization studies can be broadly divided into two types. The first type is cohort studies—those that begin with some knowledge about early hormone exposures, and investigate whether categories of exposure correlate with categories of later brain function. The cohort studies comprise many studies of people with unusual hormone exposures, as from the condition congenital adrenal hyperplasia (Berenbaum 1999; Meyer-Bahlburg 2001; Hines, Brook and Conway 2004), as well as studies of offspring from hormone-treated pregnancies (e.g. Ehrhardt, Grisanti, and Meyer-Bahlburg 1977; Reinisch and Sanders 1992), and some more recent studies that track proxy measures of fetal hormones in non-clinical populations (Knickmeyer and Baron-Cohen 2006). The second type is case-control studies—those that begin with some knowledge about the behavioral or functional phenotype (the presumed outcome of the brain organization process), and work backwards to search for evidence that distinct phenotypes correlate with distinct hormones on the front end of development. The case control studies almost entirely comprise within-sex/gender comparisons of sexual minorities and cisgender (i.e. non-transgender) heterosexuals (Gladue and Bailey 1995; Lalumière, Blanchard, and Zucker 2000; Byne et al. 2001; Blanchard and Lippa 2007).

In other words, these two broad sets of studies involve studying either unusual inputs (i.e. unusual prenatal hormone exposures) or unusual 'outcomes'—that is, studies that compare people with psychosexual phenotypes that are considered distinctive, such as heterosexuals compared to homosexuals. In epidemiology, where quasi-experimental or observational studies are the norm, it is well recognized that causal associations are only established when evidence from substantially different research designs converges (Cook and Campbell 1979). We review the various associations that are examined in the cohort and case-control studies bearing on the brain organization or 'hardwiring' paradigm in humans. For the paradigm to be well supported, evidence from the different designs should allow us to trace one or more complete paths from early hormone exposures, through specific psychosexual traits, and back again to early hormone exposures.

In fact, however, it is not possible to trace such complete loops, because these two types of studies give us irreconcilable data, with different designs showing associations between different specific behavioral domains, and contradicting dose-response expectations. The following summarizes the evidence for various two-way associations between prenatal hormones and five broad domains of traits that are hypothetically sex-differentiated by hormones, as well as between these various traits.

For genetic females, at first glance, it seems that there is one complete 'loop' of evidence supporting this paradigm, which relies especially on evidence from girls and women with congenital adrenal hyperplasia (CAH). Yet there are important problems with building the brain organization paradigm on this case. In spite of the fact that they have the highest prenatal androgen exposures of any known group of human females (and in spite of common claims that there are differences in other domains), only childhood toy preferences and adult sexual orientation are consistently different in girls and women with CAH compared to unaffected women and girls. Moreover, the much-touted increase in same-sex orientation among women with CAH is generally limited to fantasy or attraction, while rates of actual same-sex "behavior are only slightly elevated, if at all, especially when women with CAH are compared to women in the general population (Sell et al. 1995; form et al. 2003; Savin-Williams 2006) rather than to their own same-sex relatives (Zucker et al. 1996; Hines, Brook and Conway 2004; Gastaud et al. 2007; Meyer-Bahlburg and Dolezal 2008). The possible exception to this pattern is women with CAH who were initially assigned as male, in whom same-sex behavior and identity do seem to be elevated above "population rates (Meyer-Bahlburg and Dolezal 2008).

Even these differences cannot be conclusively attributed to hormones, in part because CAH has wide-ranging effects on postnatal physiology (e.g. disrupted synthesis of mood-regulating hormones; short stature; and high rates of obesity, cystic acne, hirsutism, and male-pattern baldness) (White and Speiser 2000; Lin-Su et al. 2008; Jordan-Young in press). As a group, girls with CAH also have very unusual rearing experiences and extremely intrusive medical interventions and monitoring, due both to concerns about 'virilization' and to the difficulty of achieving hormone control in the condition (Karkazis 2008).

Notably, no behavioral differences are found in the only other group of girls and women who are known to have been exposed to high levels of 'masculinizing' hormones in utero, namely those exposed to diethylstilbestrol (DES), a synthetic estrogen with androgenic properties in most species studied (Lish et al. 1992; Titus-Ernstoff et al. 2003). In particular, in spite of some early reports that DES-exposed women were more likely than unexposed comparison woman to be left-handed (Schachter 1994; Scheirs and Vingerhoets 1995; Smith and Hines 2000) or lesbian or bisexual (Ehrhardt et al. 1985; Meyer-Bahlburg et al. 1995), these associations could not be replicated when repeated with more appropriate comparison groups, including the only large, longitudinal cohort study of psychosexuality and DES exposure, which included nearly 4000 DES-exposed women (Titus-Emstoff et al. 2003).

Among genetic males, there is an even greater dissociation between evidence from research designs that begin by comparing people with different psychosexual profiles (case-control designs), on the one hand, and studies of hormone-exposed subjects (cohort designs), on the other. In particular, no cohort design shows a consistent correlation between prenatal androgens and *any* aspect of psychosexuality in genetic males (Jordan-Young 2010).

Ethical Shortcomings

For all the reasons outlined above, the hardwiring paradigm is plainly unscientific; it is at odds with many kinds of evidence both about the nature of traits and about the actual observed associations between early hormones and sex/gender in humans. Given this, continued use of the hardwiring metaphor is also unethical.

The hardwiring paradigm locks neuroscience studies of sex/gender into a framework that implies permanence for any randomly observed correlations between sex/gender, on the one hand, and brain structure or function, on the other. It encourages ongoing material and social investment in the primacy and irreducibility of sex/gender differences. In particular, the notion of innate sex differences has led both lay observers and some scientists to suggest that social policies directed toward gender equity in education, occupation, or other aspects of social life are either useless or actually damaging (Holden 2000; Udry 2000; Hewlett 2002).

Hardwiring is an unethical metaphor because it says 'what is, must be.' That would be scientifically unsatisfying even if sex/gender were simply a domain of difference, rather than a domain of power relations and marked inequalities. But the continued existence of sex/gender inequalities adds an additional problem. The hardwiring paradigm erases the effect of the social world in producing sex/gender differences, so that sex/gender hierarchies appear natural. Neuroscientific explanations of sex/gender differences have added new allure to an old-fashioned sexism (Fine 2008b). The endorsement by neuroscientists of innate accounts of differences has inevitably reinforced the status quo and non-interventional policies. This has been amplified also by the popularization of these ideas in the press. In a study that appeared in 2004, Victoria L. Brescoll and Malienne LaFrance examined 290 articles taken from 29 U.S. newspapers which reflected, more or less explicitly, whether the cause of a given sex/gender difference was innate or acquired. These authors found that the ideology of the newspaper—established by taking into consideration its political view on a selection of issues (e.g. presidential endorsement and whether women should be admitted to military academies)—influenced the way in which the scientific research was addressed. More specifically, conservative newspapers were more inclined to attribute sex differences to biological cause than were liberal newspapers. Moreover, Brescoll and LaFrance further demonstrated that the type of explanation endorsed by the newspaper influenced the beliefs of the readers.

As Cordelia Fine (Fine 2010a), we (Young and Balaban 2006) and others have documented, scientists who double as popularizers of the sexed brain knit more than a few elaborations and conjectures together with neuroscientific facts to support the hardwiring paradigm (Baron-Cohen 2003; Brizendine 2006; Swaab and Garcia-Falgueras 2009). But we suggest that even careful studies of sex/gender differences, at this time, may be missing the point. Rather than continuing to build and revise the list of differences (which are inevitable so long as social life is pervasively structured by gender), the question to ask now is *why* is it that we want to know about sex/ gender differences? What do we wish to do with or about them? We write this, with humility and some concern, as scientist-critics who have both written books reviewing sex/ gender difference research, for audiences that we hope will be broad. So we aren't picking on others here, but raising concerns about where we hope that we might all go from here, most productively.

WHERE SHOULD WE GO NEXT?

We close by considering the messages we convey by continuing to invest our scientific resources in extending, revising, or refining the catalogue of sex/gender differences. One very strong message is that sex/gender differences are crucial fundamental facts, that simply knowing about them in minute detail will guide us in important ways. Together with the pervasive belief that such differences are original, essential—that is, innate—this catalogue of differences distracts us from the extensive evidence on how the shape of sex/gender differences changes across both time and place, and can be altered by both natural experiences and deliberate interventions.

If we want to know about sex/gender differences because we are interested in empirically grounded understanding of human development and potential, we can look in two promising directions. First, we can focus directly on plasticity, instead of using it as background information against which we interpret findings of difference. We might build on Feng et al.'s video game intervention (described above, Feng, Spence, and Pratt 2007) by identifying some skills and traits that we can agree are desirable, and for which there seem to be reliable sex/gender differences at some point in the lifespan—mental rotation is a good example, but there are others like strong contextual verbal ability or empathy. Why not decide that we want to cultivate these skills or traits, and encourage creative research designs that would help us to establish effective strategies for doing so? Likewise, we could build upon experiments that show how invoking either positive or negative stereotypes can stimulate sex/gender differences as large as those that are usually taken to be innate (Hyde and Mertz 2009).

A second promising direction is to turn our backs on sex/gender differences. Because sex/gender differences are so mesmerizing, and because we ourselves are immersed in the "cultural frame of gender" (Ridgeway 2009), we may do much better to understand development and plasticity by looking at other kinds of variation, where our models and our interventions are less confounded by the complex and unavoidable overlay of gendered socialization and ingrained research hypotheses. Sex/gender differences exist, but so do differences between groups that we might want to define on many other dimensions—social class, occupation, development index or global region, specific training experiences, to name just a few. And each of these categories are themselves heterogeneous; more research on the ways in which sex/gender patterns in brain and behavior are specific to social class, ethnicity, and nation might provide much more illumination on the concrete mechanisms through which the social world shapes behavior, and even becomes embodied (brain) difference. Suggestive evidence in this direction is available from cross-national and ethnic comparisons of sex/gender difference in math and science tests. For example, both the size and the direction of sex/gender difference vary across ethnic groups. In the U.S., whites show the familiar pattern that boys score slightly higher (d = 0.13), whereas Hispanics show no discernible sex/gender difference (d = 0.00), and African Americans and Asian Americans show small differences favoring girls (d = –0.02 and d = –0.09, respectively) (Hyde and Linn 2006). Further, in 2008, Guiso et al. analyzed mathematical and reading test scores (from the Programme for International Student Assessment—PISA) of 276,165 male and female adolescents from 40 different countries; in particular, the mathematical gap favoring boys is attenuated, and sometimes even reversed, depending on a measure of sex equity of the country (Guiso et al. 2008). These and similar findings clearly should remind us that we are not measuring 'biological sex' when we record students' sex/gender. Instead, we are measuring a composite variable that includes sexism, as well as other aspects of social structure and experiences, including regionally and ethnically specific modes of 'doing' sex/gender.

Another compelling example of dimensions of difference that might prove more tractable than sex/gender for focused study is Maguire and colleagues' fairly recent data on differences in neural structure and even function in a group defined only by occupation—namely, long-term taxicab drivers compared with those who haven't driven cabs (Maguire et al. 2000, 2003). Why not follow Maguire's lead, and think about other occupations that might involve sufficiently distinct tasks that we could trace their effects in actual structural differences or brain activation patterns?

Given pervasive gender socialization and widespread gender segregation in occupation and family responsibilities, it is utterly predictable that we would observe group-level differences between men and women in various cognitive functions. It is frankly somewhat surprising to us that we do not see greater differences and less overlap, and also would not be especially surprising to see more structural differences than there seem to be. What's the big deal? Certainly it makes a huge difference to your daily life and activities whether you are male or female, without question more difference than whether or not you are a taxicab driver. Continuing to treat findings of sex/gender difference as if they are revelations feeds the commitment to and mystification of sex/gender differences, and distracts us from serious science.

Sex/gender is, for most purposes, at best an imperfect proxy of the variables we actually need to understand. Recent analyzes by feminist epidemiologists show that studies that treat 'sex difference' as an explanation actually obscure more than they explain (Krieger 2003; Messing and Stellman 2006). Instead of treating sex/gender as the denominator of difference, it turns out to be far more informative to focus on specific mechanisms (such as hormone activity, body size differences, occupational differences, and co-morbidities) that themselves show meaningful variability within sex/gender groups that are routinely treated as homogeneous. Data on differences in neural structure and function in groups that are defined only by occupation and hobbies, including pianists and jugglers, in addition to the aforementioned taxicab drivers (Maguire et al. 2003; Driemeyer et al. 2008; Lappe et al. 2008) offer a useful start for thinking about how pervasive organization of daily tasks and social assignment of appropriate emotion, movement, and affect by gender becomes embodied as measurable 'sex difference.' Most importantly, it provides a ground for thinking about what we actually wish to do with the information we have about difference and variability. What traits do we value, and what might we wish to cultivate?

Steven Rose and colleagues (2009) wrote that "In a society in which racism and sexism were absent, the questions of whether whites or men are more or less intelligent than blacks or women would not merely be meaningless—they would not even be asked." It follows that it would be better to abstain (at least for now) from trying to deal with unanswerable questions about origins of sex/gender differences, or to continue building a catalogue of 'differences' when we know that this catalogue is neither stable nor innocent.

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CHAPTER 13

Making Males Aggressive and Females Coy: Gender across the Animal-Human Boundary

Erika Lorraine Milam

Sexual selection, as conceived by Charles Darwin in the mid-nineteenth century, explained the origins of phenomena in the animal kingdom that could not be attributed to natural selection—why males and females differed in their appearance and behavior and the presence of beauty.[1] To explain beauty in the natural world—from the gregarious displays of wild turkeys in the spring to the vibrant contrast of red cardinals against the winter snow—without reference to our own pleasure presented a difficult problem for biologists committed to naturalistic explanations. Darwin suggested mate choice as a solution: beauty was useful for animals because it helped them attract mates. The idea of choice vexed other zoologists, however, because it seemed to grant to animals the same capacity for aesthetic appreciation and decision making that humans enjoyed. As Donna Haraway's *Primate Visions* (1989) so vividly illustrates, the relationship between the animal and the human informs our scientific and cultural perceptions of what it means to be male or female today, much as it did for Darwin. In this article, I interweave two polarities, animal and human, male and female, to elucidate the evolution of biological constructions of animality and gender. In the early decades of the twentieth century, few biologists found Darwin's proposed mechanism for sexual selection—female choice—plausible, as they rejected the idea that animals possessed the capacity to aesthetically evaluate and choose a mate. Animals in the early twentieth century functioned as mechanical foils against which zoologists sought to define what it is to be human. After World War II, however, animals as social beings became sources for understanding our human instincts. Men were quickly bestialized because of their association with aggressive, warlike behavior, whereas women were exempted from such degenerate stereotypes. Yet, less than a decade later, biological anthropologists and zoologists began to frame female animals as possessing equal agency, albeit by acting sexually coy and exercising their natural prerogative—female mate choice. A history that combines theories of animal and human behavior thus provides a dynamic tool for thinking about the scientific construction of sexual roles throughout the century.

Feminist scientists and historians have incisively explored the gendered dimensions of Darwin's theory of sexual selection.[2] Darwin proposed two mechanisms by which sexual selection might function. The first, female choice, took place when males displayed their finery and females compared the males, selecting one with whom to mate. The second, male-male competition, occurred when males fought over access to females and resulted in the development of armor, horns, antlers, or other weapons of minor destruction. The result of sexual selection over time was twofold: the traits selected helped animals obtain mates and leave more offspring (rather than fit their environment, as expected with natural selection), and males and females began to look and act differently—females became coy and males ardent.

Although "coy" as a term applied to the mating behavior of female birds and women has a long tradition (e.g., see "Tuesday" 1756, 162), in zoological circles coy females came to be primarily associated with Darwinian sexual selection and Darwin's description of females as requiring courtship to overcome their natural tendency to run from males (Darwin 1871, 1:273). Darwin seems to imply that despite their apparent passivity, by differentially fleeing suitors females were choosing either the least distasteful or most attractive male with whom to mate. Darwin's rival discoverer of natural selection, Alfred Russel Wallace, also used the term in debates over female mating behavior (Wallace 1871, 178). Following their example, agronomist Angus John Bateman described the reproductive behavior of female fruit flies as passive (Bateman 1948, 350). In turn, citations of Bateman's work on the "traditional coyness of the female" appeared again among evolutionary biologists in the late 1960s (Williams 1966, 183; see also Trivers 1972). By the mid-1970s, these evolutionary accounts of coy females were gaining wider readership among a popular academic audience (Wilson 1975; Dawkins [1976] 2006). Yet not all zoologists meant the same thing when they used the word "coy." For Darwin and Wallace, for example, being sexually coy was a passive quality; it was a biological consequence of being female (Darwin 1871, 1:273; Wallace 1871, 178). For evolutionary biologists Robert Trivers and George Williams, on the other hand, females actively played coy as part of an evolutionary strategy to evaluate the potential commitment of the male to participating in offspring care (Williams 1966, 186; Trivers 1972, 148–49). This difference between biological identity and reproductive strategy underpinned two rather different ways of looking at animal behavior as the result of instinct or negotiation.

The standard history of sexual selection—and by association, female choice—frames these works in a single linear heritage, carrying Victorian stereotypes of "eager" males and "comparatively passive" females into the 1970s (Darwin 1871, 1:273). It is a story of mostly male biologists who either (in a sympathetic reading) botched the transition from their favorite model organism to primate behavior or (less sympathetically) imposed their own biases about sex and gender onto their animal subjects.[3] Either way, for many feminist critics of evolutionary accounts of human behavior, zoologists' conclusions became suspect for naturalizing a vision of women as behaviorally passive, sexually coy, and inevitably maternal.[4] This was so much the case that biologists like Sarah Blaffer Hrdy and Patricia Gowaty, who identify as both feminists and evolutionary theorists, have felt the need to justify their evolutionary research as feminist (Hrdy 1999a, xiii–xxxii; Gowaty 2003).

In this article, I add another dimension to this history: the relation between animal and human minds. On both sides of the Atlantic, theories of animal minds in the early twentieth century—including both American behaviorism, which focused on the capacity of conditioning to alter the behavior of an animal or person (Watson 1914; Skinner 1938; Lemov 2005), and European ethology, which focused instead on the evolution of behavior in natural environments—tended to frame animal behavior in mechanistic, reactive terms.[5] Biologists from both traditions emphasized a fundamental gulf separating human and animal minds. Humans could manufacture and use tools to manipulate their environment, communicate abstract concepts through language, and choose rationally—animals could not. Thus, for much of the century following Darwin's publication of *The Descent of Man, and Selection in Relation to Sex* (1871), biologists were largely unwilling to grant animal minds the cognitive capacity of choice that Darwin's theory seemed to require.

By the 1960s, however, biologists and anthropologists increasingly described animals as active agents due to their concern with the seemingly innate tendency of men to wreak war and violence in society. The pop-ethology and pop-anthropology literature of the 1960s emphasized the importance of atavistic animal instincts in humans as a possible cause of male aggression (Ardrey 1961; Lorenz 1966). Men lacked appropriate outlets for their natural aggression, and even in combat the ability to kill at great distances prevented one-on-one physical encounters that might diffuse soldiers' aggressive drives. Simultaneously, American and British biological anthropologists took advantage of the newly decolonized African savanna to study other social primates.[6] Baboons were seen as the prime representative of a primate species in an ecological transition from trees to savanna, much like human ancestors had been millions of years earlier (DeVore 1965). Primatologists saw parallels between the importance of male aggression in structuring baboon social interactions and the issue of aggression in humans. In equally gendered stereotypes, primatologists and evolutionary theorists saw women and female primates as less likely to succumb to the ravages of anger or the aggressive instincts that beset men or male baboons. In other words, through a newfound concern with the instinctual aggression of men following the Second World War, male animals were rehabilitated within theories of animal behavior into active, plotting, hunting, and social beings. This new vision of animals as capable of manipulating their social environments began to collapse the hard and fast division between human and animal minds that had largely dominated the study of animal behavior in the first half of the twentieth century.

The minds of female animals were rehabilitated secondarily within this framework, through the recognition that female choice in animals could actively alter male behavior and, in humans, that women's work contributed substantially to the internal social dynamics and long-term survival of the group. Biologists and anthropologists appropriated sexual selection and female choice as active evolutionary strategies only after animal minds were considered capable of true choice. Additionally, even playing coy represented only one possible mating strategy females might adopt. As biologists came to know more about female social interactions, any adherence to a strict promiscuous-male/coy-female framework came under attack from within the scientific community.

In short, during the first half of the century, scientific attempts to use choice as a biological characteristic distinguishing humans from other animals yielded theories of animal behavior that emphasized the unconscious nature of animal actions. Biologists discounted Darwinian female choice not because it involved females but because the theory required that animals possess the mental capacity to choose a mate. During the second half of the century, biologists and anthropologists began to investigate social interactions in primates and other animals as models of early human societies. As scientists recognized that humans were more animal-like than they had thought, animals reciprocally became capable of being more human—more active, more competitive, more coy—than in earlier decades. Biologists made females coy as a result of making males aggressive, and both moves required rethinking a fixed boundary between animals and humans.

NEGOTIATING CHOICE: ANIMAL MINDS AND HUMAN INSTINCTS

In the decades following Darwin's publication of *The Descent of Man, and Selection in Relation to Sex* (1871), most biologists believed that humans differed fundamentally from animals, whether because humans possessed a soul whereas animals did not or because humans, through the development of conscious thought and civilization, were no longer governed by the same natural forces that dictated animal survival and reproduction. Turn-of-the-century concerns over the increasing remove of human civilization from nature inspired both conservation movements, to preserve what little wilderness remained, and eugenics movements, to protect the future of Western civilization now that natural selection was no longer at work in human society (Richardson 2003; Kingsland 2005). In studies of animal behavior, similar concerns led biologists to frame the actions of animals as the result of either behavioral or evolutionary programming.

Such mechanical frameworks worked well for understanding how animals learned to solve puzzles or react to a threat from another individual but not for explaining why some species were far more beautiful than others. The eye-catching plumage of many male birds posed a particular problem for evolutionary biologists because they surmised that if the brightly colored feathers caught their attention, then surely it would also attract the attention of animal predators (Kellogg 1907). By following the thread of Darwin's theory of female choice as applied to birds, we can trace changing assumptions about the animal mind throughout the first half of the twentieth century.

Darwin's theory of natural selection, based on competition among members of the same species for limited ecological resources, was a powerful tool that he used to explain the speciation of plants and animals and how they became adapted to the environments in which they lived (Darwin 1859). Yet Darwin despaired of using natural selection to explain beauty in animals because the extravagant traits so lauded by humans hardly seemed to help the animals that exhibited them survive in their local environments. If anything, the traits made the animals more visible to predators and made it harder for them to escape. Additionally, he could not see how natural selection might explain why males and females differed in their appearance and behavior. Surely any trait that helped a male rabbit escape a fox would also help a female rabbit! Sexual selection provided an answer, which Darwin applied to animals and humans equally. In humans, he suggested, sexual selection might explain the origin of races (Desmond and Moore 2009), which he saw as providing a similar problem to that of sex differences: both were stable variations in the appearance of groups of individuals within a single species. I mention this by way of illustrating that for Darwin animal and human minds were distinguished by differences in degree, not in kind (Richards 1987). For example, in *The Descent of Man, and Selection in Relation to Sex,* Darwin argued that just as a human breeder could "give elegant carriage and beauty to his bantams, . . . female birds, by selecting . . . the most melodious or beautiful males, according to their own standard of beauty, might produce a marked effect" (Darwin 1859, 89). Like people, animals could compare and evaluate the aesthetic beauty of other individuals.

Many of Darwin's contemporaries, including Wallace, found his failure to categorically distinguish between animal and human minds problematic at best. Framed within his increasingly spiritualist understanding of life, Wallace argued instead for a strong divide between human and animal mental capacities. Whereas animals were subject to natural selection as a *mechanism for environmental adaptation, human capacity for mental deliberation allowed us to escape its ravages. Wallace insisted that animals could not choose and therefore sexual selection was not at work in birds, even though mate selection could be a powerful force of evolution in human society. In his book The* Socia*l* Environmen*t* an*d* Mora*l Progress,* Wallace wrote that "sexual selection possesses the potentiality of acting in the future so as to ensure intellectual and moral progress, and thus elevate the race to whatever degree of civilization and well-being it is capable of reaching in earth-life" (1913, 140–41).

Wallace provided his own explanation of sex differences in the coloration of birds based instead on natural selection. He contended that beautiful male plumage was a physiological result of the body's exuberance. Patches of brightly colored feathers would be produced wherever excess energy was expended, resulting in the red chest of the singing robin, for example, or the male peacock's blue train, which he delighted in shaking before the female. Wallace reasoned that males were generally more active than females, so logically we should expect that males would also be more colorful than females. The real phenomenon in need of explanation, he continued, was why the plumage of females was so consistently nondescript and brown. This Wallace easily explained as the result of natural selection for camouflage during the nesting season. If a female were caught by a predator, then she would lose her own life and the future lives of her offspring. For Wallace, then, the differences between male and female coloration were the result of natural selection for female maternal success, not sexual selection for male grandeur (Wallace 1877).

For mathematical geneticist Ronald Fisher, much as for Wallace, natural selection could explain the evolution of the organization and physical structures of animal and human bodies. He reserved the evolution of human ethics, aesthetics, and morality as the special jurisdiction of sexual selection: "All the refinements of beauty, all the delicacy of our sense of beauty, our moral instincts of obedience and compassion, pity or indignation, our moments of religious awe, or mystical penetration" were the result of conscious selection in humans (Fisher 1914, 309). Marriage selection, a form of mate choice in humans, formed a crucial part of positive eugenic discourse throughout the first decades of the twentieth century (Richardson 2003).[7] This association of choice and aesthetic beauty lay at the heart of Fisher's conviction that sexual selection was more important for the improvement of humanity's biological future than it was for animal evolution.

To explain the evolution of beauty in animals, who lacked the higher consciousness of humans, Fisher (1930) proposed a theory called "runaway" (137) sexual selection. In runaway sexual selection, female choice for a trait and the male expression of that trait became genetically linked and so coevolved together. If a female, for no particular cause, happened to prefer the male with the longest tail, then their offspring would consist of males with long tails and females who preferred long-tailed males. Over several generations, Fisher posited, the average tail length of the males would increase and female preference for long-tailed males would grow stronger. To be the longest-tailed male of the group, a male's tail would have to be longer than his father's or his grandfather's before him. Even if males with extraordinarily long and bright tails caught the eyes of predators, selection for this trait would continue as long as the males possessing the trait managed (on average) to leave more offspring than those males with duller or shorter tails. Through female choice, then, evolution could drive populations to express traits that decreased individuals' chances of survival (Fisher 1930, 131–39).

Despite his use of bird plumage in describing the effects of runaway sexual selection, it seems likely that Fisher still had human evolution in mind. For example, he used the runaway process to explain male heroism in battle (Fisher 1930, 162, 247). As with bird plumage, he found it difficult to explain altruistic tendencies solely in terms of natural selection, which he thought should act to cull such phenomena from a population very quickly. He hoped that human mate choice for good, moral characters would help the British population recover from their huge losses of promising young men in World War I. Yet mate choice gone wrong could be devastating. He worried that the evolutionary future of Britain was in grave danger because men and women of the working classes were apparently reproducing at a higher rate than their more genteel countrymen. Fisher devoted the second half of *The Genetical Theory of Natural Selection* (1930) to describing the evolutionary causes of contemporary social degeneration and outlining a plan of economic incentives designed to alleviate the difference between the birth rates with which he was so preoccupied. Although Fisher used mate choice as a tool to describe the evolutionary past and future of human society, he doubted the ability of any biologist to demonstrate the efficacy of female choice in animals.

Another biologist writing in the late 1930s who deemed it unlikely that animals could choose their mates was zoologist Julian Huxley. Huxley argued that apparent female choice in animals was really the result of some males courting more vigorously than others and that most sex differences in appearance and behavior could be attributed to the need for sex recognition, aggression toward potential competitors, and warnings to predators (Huxley 1938). To him, all these factors were really natural selection, not sexual selection. Based on earlier observations of the courtship behavior of the great crested grebe, Huxley noted that most courtship displays took place after pairing. Courtship was thus key to extended pair bonding, not to the initial choice of mates. Huxley drew a bright line between human and animal cognitive abilities. A popular textbook that Huxley coauthored proposed that "the human lover woos with the cerebral cortex, he (or she) is plastic and responsive, and adapts the means to the occasion." In stark opposition, "the impassioned bird woos ardently but automatically with the corpus striatum. . . . The human lover may do a thousand things; the courting bird is an elegant determinate machine" (Wells, Huxley, and Wells 1931, 742). By describing animal behavior as automatic and determinate, Huxley hoped to professionalize the study of animal behavior and distance the growing field from the anthropomorphic stories he associated with amateur writings (Burkhardt 2005).

Huxley also worked with a group of biologists seeking to make zoology more evolutionary in focus. The research of population geneticists like Theodosius Dobzhansky and zoologists like Ernst Mayr had transformed definitions of female choice from a matter of beauty or aesthetic comparison to one of recognizing a mate of the appropriate species.[8] Rather than observing the mating behavior of a few individuals, evolutionary biologists turned to statistical analyses of many copulations. If only a male of the right species could stimulate a female to mate, then biologists could tell if two populations were really separate species by allowing them the opportunity to interbreed. If just a few individuals did, say less than 1 percent, then the populations were reproductively isolated—they were "good" species. If a much higher percentage of individuals interbred, perhaps 30 percent, then the two populations were simply subspecies. Population geneticists began to use female choice as a diagnostic tool to analyze the process of speciation rather than looking at mating behavior as a mechanism for changing the appearance of a single species.

Although most animals could fit within this new evolutionary agenda, there were still a few species that caused evolutionarily inclined zoologists a bit of a headache—most notably the bower birds. Male bower birds decorate their bowers with color-specific odds and ends, and they arrange the twigs and bits of color into amazing display arenas (Marshall 1954). Even as late as 1944, a popular article described the underlying function of the male's behavior as having "gone far beyond" a "purely utilitarian usage" (Chaffer 1944, 179). The author further posited that the birds derived "a great deal of satisfaction and pleasure in such activities" (Chaffer 1944, 180). Their penchant for play and aesthetically pleasing architecture set bower birds apart as prime candidates for wanton anthropomorphism.

Part of an answer came from an Australian earning his PhD in physiology at Oxford in the 1950s. Alan John "Jock" Marshall was fascinated by the possible correlations between bower birds' exotic behavior and their internal reproductive physiology. As a result of his research, Marshall suggested that the behavioral antics of male bower birds fulfilled a biologically necessary function—these behaviors helped both sexes come into sexual readiness at the same time (Marshall 1954, 69–71). Marshall considered himself "reasonably sure that neither intelligence nor conscious estheticism is involved in the bower birds' behavior. The bird's selection and placement of decorations in its bower is purely mechanical" (Marshall 1956, 52). The architectural marvel of a bower itself he attributed to a male's nervous activity as he waited for the females to become sexually responsive. Marshall earned the respect of his peers by providing an account of bower bird behavior that eliminated the need for recreation and aestheticism. After reading Marshall's book, one reviewer brought this point home by suggesting that bower birds provide "an extravagant example of the amazing complexity of behaviour which instinctive pattern can initiate and control."[9]

Like Marshall and the zoologists who preceded him, British theoretical biologist John Maynard Smith was interested in explaining the evolution of beauty within a single species, but he questioned whether such extravagant behavior and colorful plumage could be so easily dismissed as resulting from a need to coordinate the sexual readiness of males and females and to ensure species-appropriate couplings. Maynard Smith posited that the tail of the peacock could be explained only as an advertisement to attract the attention of females. He asked his readers to imagine bird plumage as a signal. If the point of the plumage was to function as a simple traffic sign—*to go to Brighton, turn right*—then the plumage needed to be easily recognized but not flashy, like the simple black and white coloration of black-headed gulls. Yet advertisements, he suggested—*Come to Brighton!*—were only employed when the viewer had not yet made up her mind if Brighton was truly where she was headed (Maynard Smith 1958, 237, fig. 47). Maynard Smith argued that although many animal courtship displays could be reduced to functionalism, very extravagant displays should be understood instead as competitions for the attention of females. In other words, sexual selection was still needed. When a male failed to attract a female, it was not because of a lack of interest on the part of the male. The signal worked, but his lack of ability failed to arouse the female. Beauty and female choice were linked once again in his explanation of courtship behavior. Yet Maynard Smith's chapter on sexual selection failed to attract much attention when it was published in 1958. Not until fifteen years later did evolutionary explanations of beauty in the animal kingdom once again enter the zoological spotlight.

In the first half of the twentieth century, biologists depicted male behavior as the result of biological imperatives and rejected female choice in animals because of the cognitive functions they assumed were necessary for choosing a mate. If we take as our baseline the mechanical assumption that dominated much research in animal behavior in the first decades of the twentieth century (that animal actions should best be understood as evolutionary or psychological reactions to their environment rather than an active intervention), then the growing biological interest in sexually aggressive males competing for the attentions of females stands out as peculiar and in need of explanation. To understand this transformation in the field of animal behavior, we must turn to a slightly different community of scientists—those explicitly interested in the evolution of humanity.

NEGOTIATING GENDER: AGGRESSIVE MALES AND COY FEMALES

The 1960s was a decade imbued with violence. In the United States, the GI experience in Korea had presaged the discontentment and eventual anger with the war in Vietnam that now lit up television screens (Hallin 1986; Anderegg 1991). Civil rights protesters became increasingly frustrated with the slow pace of change, leading to urban unrest and riots in Watts, Detroit, Newark, Baltimore, and other major cities around the country (Gerstle 2001). Newspapers carried accounts of political revolutions in Africa, Asia, and Latin America. Combined, these events emphasized the importance of violence in structuring the political and social events of the day. Given this context, perhaps it is unsurprising that the rehabilitation of the animal mind began with aggression and began in anthropology.

Anthropologists in the 1960s self-consciously distanced themselves from racist accounts of human evolution common before the Second World War, hoping to replace them with a vision of humanity that held all cultures as equally complex and valuable (Proctor 2003). They also sought to understand why humans, of all animal species, were capable of killing each other (Carthy and Ebling 1964; Proctor 2008). Archaeologists, cultural anthropologists, and physical anthropologists produced a vision of humanity based on universal roles for men and women grounded in biological instincts. Man the hunter (or man the killer) provided food and social status for his family, while woman the gatherer (or woman the mother) raised the children and ran the household. Ironically, as anthropologists sought to distance themselves from overtly racist accounts of human evolution, they reinscribed sex differences as the biological basis of gender in all human societies (Haraway 1989).

In archeological reconstructions of human history, for example, the use and manufacture of weapons was often taken as a key process driving the continued evolution of human society. In 1959, Mary Leakey and her husband Louis Leakey shocked the world with their announcement of the 1.75 million-year-old *Zinjanthropus* in the Olduvai Gorge in Kenya—at the time, the oldest known "manlike creature" (Leakey 1961, 564; Ward 2003). In *National* Geographi*c Magazine,* the Leakeys vividly described their reconstruction of human social evolution based on their archeological finds, accompanied by a six-panel, two-page image of the place of “Zinj” in human history (Leakey 1961, 570–71). According to the copy above the image, the first panel depicts the “earliest known hunters” from the site, who lacked weapons and survived by catching their food with their bare hands. In the second panel, Zinj brings down a zebra colt with a large wooden club, with the caption declaring him “a true man in the tool-making sense.” The third panel portrays “the dawn of the spear,” in which the putative descendants of Zinj work together to kill a large swamp antelope. The fourth panel represents a time of drought and climate change at Olduvai Gorge and thus pictures only small desert rodents. Hunters return in the fifth panel, as men and women gather around a large elephant-like creature stuck in the mud. The men carry spears and the women rocks. The final panel illustrates cheering men (still carrying spears) who have successfully stopped a giant ram in its tracks by throwing a Chellean bola around its front legs. Later in the article, Leakey (1961) described the virtues of the bola at greater length, calling it “an ingenious arrangement of three hide-wrapped stones connected by thongs” that when tangled around the legs of large running prey would bring them crashing to the earth (579). So what distinguished “true man” from his bestial brethren in this developmental sequence of humanity? Not the ability to hunt or to plan ahead for the hunt, nor the ability to communicate with other members of the group for the purposes of hunting together—these activities were clearly depicted in the first panel. It was the manufacture of tools, and weapons in particular. As the rest of the article made clear, the manufacture of weapons and humans’ evolutionary success was the work of men.

Contemporary research on extant so-called Stone Age cultures similarly emphasized the importance of male hunting and female domestic labor. For cultural anthropologists, it made sense to theorize about the culture of early humanity based on what they knew about human societies that had remained relatively free from contact with Western culture and technology (Clark 1968; cf. Berndt 1981). The pages of *National Geographic,* television specials, and books written by anthropologists claimed that each new tribe was more “primitive” than the last (Kirk 1969; von Puttkamer 1975). To be fair, these anthropological studies emerged out of concern that such cultures would inevitably be lost to the inexorable creep of technological progress through contact with the Western world. Yet these studies also reflected the same gendered division of labor as archeologists’ visions of early humanity: man the killer, women the reproducer (Tanner 1981).

By the late 1960s, however, the idea of using “Stone Age” human cultures to stand in for man at the dawn of humanity became increasingly unpalatable to anthropologists. Both physical and cultural anthropologists saw the promise of using primate societies as a mirror or foil for reconstructing a universal human nature from the animal side, rather than the human (Le´vi-Strauss 1968). Using primates rather than human cultures served to equalize all contemporary human cultures as more complex than early human societies. Additionally, if social behaviors were identified in the primate species that accorded with anthropological knowledge of human cultures, then it seemed likely that such traits were universal for all humanity. Two species dominated early discussions of primate behavior—baboons and chimpanzees.

To biological anthropologists like Irven DeVore (1965), baboons were the primate species that most closely adhered to the ecological environment that characterized the dawn of humanity, which made them an excellent source of information about our ancestors. Baboons—like early hominids, he suggested—lived partly in the safety of the trees and partly in the open savannah; they were highly social, and the males banded together to protect the females and young in the event of a threat (DeVore 1965). Male dominance and aggression appeared to structure their social organization even more than in humans. According to biological anthropologists Lionel Tiger and Robin Fox (1971), male baboons entirely controlled the hierarchical status relations of the group, while females bonded with their offspring. In Fox's writings in particular, the ultimate family unit was simply mother and child, while the males drove the intellectual evolution of hominids through their ability to negotiate their dual desires for sex with females and for social status derived from aggressive encounters with other males (Fox 1968). In a telling moment, Fox (1968) asked offhandedly about the other sex, "Was she simply a passive mechanism for passing along the genes of the big-brained males?" (93). His explicit answer provided only one way in which females might have contributed to the evolutionary progress of humanity: through concealed estrus, females made themselves constantly available for sex, thereby forcing males into the role of provider and into semipermanent familial relationships. Through the late 1960s, the primate literature largely concerned itself with how aggression and dominance relationships in males structured monkey, ape, and human societies and evolution (Zuk 1993).

Not all views of the barely human were quite so dismal. Jane Goodall, supported by Louis Leakey, believed that humans' closest living relatives, the great apes, were better models for human behavior than baboons (Strier 2003). This assumption underpinned Leakey's patronage of the young women who ventured into the wild to study great ape behavior in nature rather than zoos: Goodall's work with chimpanzees in Tanzania, Dian Fossey's research on upland gorillas in Rwanda, and Birute´ Galdikas's studies of orangutans in Indonesian Borneo (Haraway 1989). Goodall's initial research painted a kinder picture of early humanity than that provided by DeVore's baboons. In her first article for *National Geographic,* Goodall suggested that chimpanzee babies played much like human children and that adult chimpanzees led rich emotional lives and communicated with each other through vocalizations (Goodall 1963). Perhaps most exciting were her discoveries that chimpanzees consumed meat and manufactured tools to help them eat. In the mid-1970s, however, Goodall witnessed the gradual extermination of one group of chimpanzees by another—a shocking series of events that made her question her previous assessment of chimpanzees as gentle (Goodall 1979). The aggressors were almost always males, and she concluded that war, kidnapping, and killing were not unique to humans. In unrelated circumstances, she also observed cannibalism on the part of three female chimps—for a brief period of time, they had eaten the babies of other members in the troop (Goodall 1979). Although Goodall painted the violent males as natural aggressors, she described this new horror as a psychological abnormality that the females in question were ultimately able to overcome. In the public sphere, these events further reinforced the notion that chimpanzees were strikingly similar to humans and that males were innately more violent than females. One headline even asked, "Chimp Killings: Is It the 'Man' in Them?" (Goodall 1978).

For universal sex differences to be found in humans, baboons, and chimpanzees, many anthropologists believed that there might be a biological explanation. DeVore, for example, suggested that sex differences in primates were associated with a nonarboreal lifestyle. He reasoned that as early human ancestors left the trees for the savanna, it became more important to protect the group, and selection favored larger and more aggressive males, as it had in baboons (DeVore 1965, 62, 182). Because males were in charge of protecting the group, a female did not need to defend either herself or her young, so she would never develop into "a fighting animal" (DeVore 1965, 38). This explanation also seemed to account for the less aggressive nature of the more arboreal chimpanzees described in Goodall's early research (see also Rowell 1974). Tiger, for his part, linked aggression with exclusively male activities: "Human violence is almost exclusively a male problem linked to our hunting history. . . . War is the product of male bonding" (Tiger 1969, 42). By any account, sex differences were linked to a new understanding of males as driven by hostile encounters with other males, as possessing far more than a passive animal mind. Scientists still discussed female animal actions in terms of the nonaggressive, predominantly reactive behaviors that characterized descriptions of prewar animal behavior.

Sexual selection, in reference to either male-male competition or female choice, was not a common explanation for human or primate sex differences until the mid-1970s. At this time, field zoologists returned to a Darwinian model of female behavior that emphasized a continuity of choice across the animal-human boundary (Milam 2010). As a young maverick in evolutionary biology, Trivers (1972) provided an easily accessible theoretical basis for female choice as a mechanism of evolution by reviving the idea that females were certainly the choosier sex because they invested more in each offspring than did males. He reasoned that if females mated only once per mating season, then they would invest substantial energetic resources in variously producing eggs, giving birth, and raising offspring. As a result, females would be sexually coy—alternating bouts of intense courtship with periodic flights—to test the mettle of the males and gauge their ability to commit to offspring care (Trivers 1972, 148–49). Trivers suggested that because males could invest very little in their offspring, they had the opportunity to mate with multiple females by abandoning each mate immediately following copulation. From the female's perspective, if a male would not engage in a prolonged courtship, then he was likely not to engage in extensive offspring care. Most animals exhibited some form of differential parental investment, and therefore most animals probably exhibited both female choice and male-male competition over mates. Trivers's point was twofold: that by playing coy, female animals actively chose better partners and that such female choice was far more common in nature than biologists had previously supposed.

Trivers attributed his interest in animal and human behavior to his involvement with a post-Sputnik federally funded curriculum reform program called Man: A Course of Study, or MACOS, in the 1960s (Nelkin 1977; Trivers 2002, 57). As part of the MACOS team, Trivers worked under DeVore (and educational psychologist Jerome Bruner) writing booklets about animal behavior and reproduction for a fifth-grade audience. The booklets created for the program spanned the animal kingdom and covered salmon, herring gulls, elephants, rats, chimpanzees, baboons, and more.[10] After his experience at MACOS, Trivers decided to pursue a PhD at Harvard, where he worked closely with DeVore, and his early writings demonstrate his intellectual indebtedness to the anthropologists and zoologists involved with the MACOS project.[11] It is of little surprise, then, that Trivers's theories of sexual selection in animals tracked so well with anthropological theories of sex difference in primates and humans from the same time.

Trivers's conviction that female choice could play an important role in the evolution of animal and human mating behavior rather quickly caught a lot of attention. Entomologist Edward O. Wilson, also at Harvard, was thoroughly impressed by Trivers's ideas and based much of *Sociobiology*'s fifteenth chapter, "Sex and Society," on them (Wilson 1975). In the most recent introduction to *The Selfish Gene,* Richard Dawkins referred to Trivers as one of his "four intellectual heroes" and further suggested that "his ideas dominate large parts of Chapters 9, 10, and 12, and the whole of Chapter 8" (Dawkins [1976] 2006, xiv). It was through these two books that Trivers's research gained wider circulation among evolutionary theorists. The popularity of the word "coy," however, should probably be attributed to Dawkins, as Trivers used the word only once and Wilson not at all. Dawkins went into great detail describing "coy" as only one possible mating strategy for females—the other being "fast"—in contrast to the "faithful" and "philanderer" strategies that males might adopt (Dawkins [1976] 2006, 151). Perhaps most interestingly, both Wilson and Dawkins painted sexual behavior as a negotiation between two equally active and obstinate partners—males and females.

The subsequent flurry of research activity among field biologists took for granted that female animals chose their mates and began to question the basis of that choice. Was female choice arbitrary (as supposed by Fisher's theory of runaway sexual selection), did females judge the genetic quality of males through the expression of their exaggerated trait, or did the trait itself correlate with some direct benefit to the female, like a high-quality territory (Cronin 1991)? Biologists seemed unconcerned with the assumptions about aestheticism and mental capacity that had so preoccupied earlier generations, in part because they meant something different by female "choice" (Frankel 1994). Building on the same ethological framework Marshall used when discussing bower birds, evolutionary biologists began to suggest that naturally coy females were stimulated to mate by the male courtship displays (Hrdy and Williams 1983; Hrdy 1986). Human behavior, in other words, could be analyzed with the same behavioral tools developed to understand animal actions. Yet biologists' renewed interest in understanding the biological basis of human sexual behavior by comparing it to the courtship activities of nonprimates (following Wilson's sociobiological example) struck many biologists and humanists alike as a cavalier dismissal of those cultural and biological traits that distinguished humans from other mammals, rats, or even asparagus (Leonard 1969).

Throughout the 1970s and 1980s, feminist scientists and historians pushed against the sexual stereotypes embedded in these anthropological and biological theories (Hubbard, Henifin, and Fried 1982; Bleier 1984; Fausto-Sterling 1985). Elaine Morgan (1972) and Sally Slocum (1975) were some of the first women to vocally attack the sexism inherent in contemporary theories of human evolution and their overemphasis on hunting and meat. Critiques by others soon followed. Anthropologists Adrienne Zihlman and Nancy Tanner, for example, emphasized the crucial role of women in providing almost all of a group's nutrition through their gathering of foodstuffs and critiqued the anthropological theories of human evolution as failing to incorporate women's contributions to the ecological survival of the species (Tanner and Zihlman 1976; Zihlman 1978; Tanner 1981). Primatologists Sarah Blaffer Hrdy (1977, 1999b) and Linda Marie Fedigan (1982) suggested that mother love, far from being instinctual and kind, involved a great deal of learning and active negotiation with other members of the group to protect themselves and their young. The earliest of these critiques, by Morgan and Slocum, barely mentioned Darwinian sexual selection, whereas later evaluations of biological explanations of human difference devoted considerable attention to the theory. By the mid-1980s, referencing Darwinian sexual selection was necessary given its rising popularity (Hubbard 1990, 97–100; Cronin 1991, 113–230). Both Fedigan and Hrdy specifically took contemporary evolutionary theorists to task for appropriating Darwin's Victorian sexual stereotypes along with his theories, but for other scientists female choice offered a way of portraying females as active agents in their own evolution.[12]

The active rehabilitation of animal minds and actions may have begun with male animals and men, but it quickly extended to encompass the wide variety of strategies female animals and women might utilize to structure the societies in which they lived—from woman the gatherer to "woman the mate chooser, woman the mother, woman the aunt, woman the communicator, woman the power, woman the ritual actor, and woman the hunter" (Dahlberg 1981, xi). These newly created roles for female animals and women as active participants in their own evolution provided a place where questions of gender and sex were not easily resolved, a space where anthropologists and biologists continued to butt heads over the equally sticky dichotomy of nurture and nature (de Waal 1999). The biological females in these narratives ranged from "unaggressive, cooperative and bonded with other women" to "assertive, status-seeking, [and] dominance-oriented" (Zihlman 1985, 372).

In sum, the depiction of man as a "naked ape" in the 1960s rehabilitated the evolutionary and behavioral complexity of male animals to the detriment of their female companions (Morris 1967). Anthropologists and biologists actively appropriated coy females in the 1970s as a reaction to these earlier scientific theories about the biological basis of male aggression.

CONCLUSION

Although Darwin posited a continuity between human and animal minds, each in degrees capable of aesthetic evaluation and choice, by the first decades of the twentieth century scientists had largely rejected the notion that any animal was capable of evaluative choice. Rather, they portrayed animals' behavior as mechanical reactions to environmental surroundings and their evolutionary past. By the time Trivers, Wilson, and Dawkins refurbished sexual selection in the 1970s, male animal minds had already been transformed within biological anthropology. In the early 1960s, females may have waited for their big strong males to bring home the mastodon bacon in exchange for sex, but by the end of the decade they were actively engaged in elaborate courtship rituals that tested males' long-term commitment. As biologists and anthropologists increasingly emphasized animalistic instincts as important components of human behavior, they simultaneously began to see the antecedents of human behaviors in animal actions. These two trends of zoomorphism and anthropomorphism, respectively, were intimately linked in the 1960s. Aggressive males and coy females were thus active constructions of this scientific community, not passive importations from Darwin's century-old theory of sexual selection.

The legacy of female choice has been double-sided (Fausto-Sterling 1995).[13] Critics of parental investment theory and sexual selection suggest that the gendered stereotypes embedded in evolutionary narratives of human behavior are cultural artifacts of questionable scientific value (for a recent attempt to dismiss sexual selection entirely, see Roughgarden 2009). Other evolutionary theorists see female choice as liberating. Biologist Patricia Gowaty, for example, argues that Trivers's paper "legitimize[d] the study of female choice" (Gowaty 2003, 901; see also Vandermassen 2005). Similarly, sociobiologist and feminist Hrdy (1999a) suggests that Darwinian theory, when applied carefully to human and primate populations, yields a picture far different than that provided by 1960s anthropology—females now possess as much agency in their behavioral choices as males. Trivers, Wilson, and Dawkins may have waltzed into a controversy with anthropologists over the cultural authority to pronounce on human nature (see Segerstråle 2000), but Gowaty and Hrdy both insist that they also (perhaps unwittingly) developed a robust and powerful framework for incorporating female choice into the evolution of human social behavior.

Female choice and other theories of animal behavior as keys to human nature maintain a powerful hold over our imagination not just because we recognize antecedents of our own actions in animals but also because we have been taught to see the animal within ourselves. Due to these earlier debates over the biological basis of human and animal behavior, we can reject simple masculine-feminine and animal-human dichotomies and instead recognize the multiple and diverse strategies and behaviors that constitute sexual identity in both animals and humans.

NOTES

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1. Darwin first introduced sexual selection, including both competition between males and selection by females, in On the Origin of Species (1859, 87–89, 156–58, 196–99), and he extensively elaborated sexual selection in The Descent of Man, and Selection in Relation to Sex (1871).
2. Biologists' critiques of "coy" as a descriptor of female mating behavior have taken at least two forms: male and female parental investment may not be so different after all; and, even if females do invest more in their offspring, that does not make them passive. For example, see Hrdy (1986), Tavris (1992), Gowaty (1994), Tang-Martinez (2000), and, most recently, Roughgarden (2009). For historical and philosophical critiques of coy females, see, e.g., Bleier (1984), Haraway (1989), Russett (1989), Hubbard (1990), and Cronin (1991).
3. See Bleier (1978), Hrdy (1986), Cronin (1991), and Tavris (1992).
4. See, e.g., Tanner (1981), Zihlman (1985), Fedigan (1986), Haraway (1989), Cronin (1991), and Gowaty (2003).
5. See von Uexküll ([1909] 1957), Tinbergen (1951), Lorenz (1952), and Burkhardt (2005).
6. The strong tradition of primatology in Japan developed under a different set of cultural circumstances and is beyond the scope of this article (see Asquith 2000; de Waal 2003). It is worth noting, however, that these studies focused on both female and male roles as actively contributing to the social structure of Japanese macaques (see, e.g., Imanishi and Altmann 1965).
7. Literature that focused specifically on mate choice in animals was less common, resulting in a spottier chronology. For a more complete history of sexual selection during this time, see Milam (2010).
8. See Dobzhansky (1937), Mayr (1942), Smocovitis (1996), and Cain and Ruse (2009).
9. M.G.B., "Review of A.J. Marshall, Bower Birds," Biology (June 1955); clipped copy in Alan John "Jock" Marshall Papers, Series 15, File 3, MS 7132, National Library Australia, Canberra.
10. Many of the educational materials for the MACOS program are available online at http://www.macosonline.org/.
11. Trivers cites the work of anthropologist Asen Balikci (who developed films on the Netsilik), ornithologist William Drury (Trivers's mentor), anthropologist Richard Lee (a close collaborator of DeVore's who worked on the !Kung Bushmen), Lorna Marshall (who was approached about developing filmic materials on the !Kung Bushmen), and, of course, DeVore himself (see Trivers 1971, 1972).

12. See Fedigan (1982, 269–86; 1986, 26–32) and Hrdy (1986, 120, 122; 1999b, 22–32); see also Hrdy's preface to the new edition of The Woman That Never Evolved (1999b), "On Raising Darwin's Consciousness" (xiii-xxxi). See also Tanner (1981, 1–14, 163–67) and Zihlman (1985).
13. Since the 1980s, there has been considerable research on the evolution of sex differences in animals and people (e.g., Strum and Fedigan 2000; Clutton-Brock 2007).

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CHAPTER 14

Asking Different Questions: Feminist Practices for the Natural Sciences

Deboleena Roy

Sometimes a pipette is just a pipette. As a feminist scientist, I have been party to more than several skirmishes over my intentions of bringing feminism and science together and have found myself retreating at times into conciliatory bottom lines just to keep the conversations alive. Yes—in a science influenced by feminism, pipettes will still be pipettes, one plus one will still equal two, and as Ruth Hubbard has said of gravity, "apples will indeed continue to fall unless someone throws them up in the air" (1995, 206). I have come to realize however that for many individuals, the mere idea of mixing feminism and science together sets well—established modes of reasoning (perhaps even gravity) into topsy—turvy motion.

In the past few decades, we have witnessed outcomes of a feminist restructuring of science and it is evident now that the answer to the question "Has feminism changed science?" is "Yes!" But how has feminism changed science? According to feminist historian of science Londa Schiebinger (1999) and many more feminist science studies enthusiasts, feminism has changed science not only by inviting more women to enter into science and pointing out gender biases present in the language and paradigms of science but also by changing the ways in which science is "done." For example, Schiebinger demonstrates that feminism has had its greatest impact in such disciplines as primatology, archeology and biology by motivating scientists to "ask new questions" (1999, 187), thereby altering the scientific knowledge that is produced. I am interested in examining more precisely, however, what it means to say that feminist scientists ask new or *different* questions and the political practices that a feminist draws from in order to arrive at these different questions.[1] My interest stems from a very intimate relationship with the natural sciences.

Several years ago, I completed my Ph.D. in reproductive neuroendocrinology. The importance of my doctoral work was in its contribution to understanding the actions of hormones at the level of the brain, including the gonadal hormones estrogen and androgen, and the pineal hormone melatonin (Roy et al. 1999, 2002; Belsham et al. 1998). I was involved in research projects that examined the effects of estrogen, androgen, and melatonin on an in *vitro* cell line of gonadotropin—releasing hormone (GnRH) neurons of the hypo thalamus.[2] My scientific work contributed to evidence that suggests that the hypothalamic—pituitary—gonadal (HPG) axis in the body functions through a series of feedback loops rather than a hierarchy controlled at the level of the brain.[3] This finding has far—reaching impacts on women's health and sexuality as it also suggests that hormone—based contraceptives or hormone replacement therapies may have broader neurological implications (Roy 2007).

As a feminist scientist, I was able to contribute to a new understanding of the body through reproductive biology research. However, I could not have made this contribution without using an in *vitro* cell line model or without using molecular biology techniques. Furthermore, because of my decision to conduct research in reproductive neuroendocrinology, not a day went by during my doctoral work where I didn't face some kind of anxiety—producing dilemma.[4] These dilemmas often stemmed from my hesitations regarding which scientific questions I should ask, which scientific theories and paradigms I should follow, and which methods and technologies I should use to conduct my science. I knew that I wanted to create new scientific knowledges of the body, but I could have used some guidance with what can be referred to as my *research agenda choice.* In many instances, I wasn't sure how to apply my feminist analyses to the "technical core" of the science that I practiced.

I think that if we are willing to accept the idea that feminism and science do meet, and that feminists should engage in the production of scientific knowledge, we cannot just plant a feminist in the lab and hope for the best. Despite encouragement from within feminism for feminists to enter into careers in science and technology and thereby contribute to meaning—making processes of our time, once the feminist answers this call and dedicates herself to becoming a scientist, there exists very little support on the other end. Is it simply enough that she identify as being feminist while conducting her science? What if she faces a dilemma between the feminism that she practices and the paradigms, methods, technologies, or tools that she uses to conduct science? How can these tensions be resolved? We must begin to address these questions if we are to continue encouraging young feminists to pursue careers in science. If we want the feminist scientist to thrive, I suggest that an effort must be made to articulate concrete strategies as to *how* she can overcome her dilemmas and go about "asking different questions."

From many projects within feminist science studies, two questions are being put forward to address the tensions involved in conducting scientific research, namely: (1) How can feminism influence the ways in which we gain scientific knowledge? And (2) how can the feminist scientist produce scientific knowledge that is relevant to and considerate of those who are marginalized within dominant cultures? These two questions, I believe, relate to the issue of research agenda choice, which does not begin and end with the concern for integrating feminist epistemologies into the sciences. Research agenda choice may begin with choosing between hypotheses, but it also operates at a much more mundane level within the enterprises of science. It has an impact on many more processes of scientific knowledge production, including the everyday choices between paradigms, language, methodologies, methods, apparatuses, techniques, and the tools needed to conduct scientific research. In her work focusing on issues in the epistemology of science, Helen Longino has suggested that feminist interventions in science have helped identify "contexts of discovery" (1993, 109) and thus have shown how social values, such as gender biases, can be introduced into the sciences. However, Longino distinguishes between those feminist analyses that serve a descriptive purpose and those that involve a normative or "prescriptive" purpose. "One way to articulate the distinctions l am urging," she states, "is to treat analysis of the context of discovery as a primarily descriptive analysis of how hypotheses are generated and to treat analysis in the context of justification as involving a normative or prescriptive analysis regarding the appropriate criteria for the acceptance of hypotheses" (102).

My interest in exploring the issue *of* research agenda choice in the natural sciences corresponds to what Longino has described as analysis in the context of justification, but is not restricted to the acceptance of a hypothesis alone. I agree with Longino's assertion that "although many *of* the most familiar feminist accounts *of* science have helped us to redescribe the process of knowledge (or belief) acquisition, they stop short of an adequate normative theory" (102). Prescriptive analysis for the natural sciences is a critical area *of* scholarship within feminist science studies that must be further developed. I would suggest, however, that in order to be useful for feminist scientists in the natural sciences, an "adequate normative theory" should also be somewhat flexible and "semiprescriptive" in its gestures. Longino's own contribution toward creating a prescriptive theory that can be applied to the natural sciences involves redefining scientific objectivity and scientific knowledge in the context of communities. She puts forward her criteria for objective communities as a set of prescriptions, and suggests two important strategies in order for these com munities to function. The first strategy involves treating science "as a practice or set of practices." The second involves taking up a "model—theoretic theory of theories" (114).

Following Longino's advice, it is my intention in this paper to develop a rough sketch of a semiprescriptive analysis by treating the issue of research agenda choice in the natural sciences as a type of *practice*. Other feminist science scholars, such as Donna Haraway (1997), Karen Barad (2003), and Joseph Rouse (1996; 2002), have also developed the idea of science as practice. Similar to Longino, they have articulated science itself as a set of practices that involves "ongoing interaction with our natural and social environments" (Longino 1993, 116). I believe that these iterations of *practice* may provide the feminist scientist with the necessary framework to create and carry through with political interventions in the sciences—where the scientist can become, or realizes that she has always been, part of the phenomenon.[5] Once she realizes that she is implicated and part of the phenomenon, which "scientific" questions she asks and to whom she asks these questions, is part of the contingency and "various performances" (Rouse 2002, 161) that get played out in any political practice. I also intend to take seriously Longino's strategy of using a model—theoretic analysis of theories. While highlighting the importance of models in the way that they structure our knowledge, Longino states:

> The adequacy of a theory conceived as a model is determined by our being able to map some subset of the relations/structures posited in the model onto some portion of the experienced world. . . . Its adequacy is not just a function or isomorphism of one of the interpretations of the theory with a portion of the world but of the fact that the relations it picks out are ones in which we are interested. A model guides our interactions with and interventions in the world. We want models that guide the interactions and interventions we seek. (1993, 115)

My intention is to suggest a suitable feminist model for the practice of research agenda choice, so that we may guide the interactions and interventions that we seek to make in the natural sciences. This way, the feminist scientist will be able to continue asking different questions—hopefully, with a little more help.

FEMINIST STANDPOINT THEORY AND THE NATURAL SCIENCES

In my search for a model that will help the feminist scientist with the practice of research agenda choice, I am interested in starting with the highly contested standpoint theory, which like many of its users, remains marginalized within mainstream philosophy of science and science studies (Harding 2004a; Wylie 2004). As Harding comments, this is "intriguing because one of its central conceptual innovations is to describe *and prescribe* the practice of taking on the cognitive, technical core of the natural sciences and their philosophies" (2004a, 26, emphasis added). While describing standpoint theory, Harding states:

> Starting thought from the lives of those people upon whose exploitation the legitimacy of the dominant system depends can bring into focus questions and issues that were not visible, "important," or legitimate within the dominant institutions. . . . Such standpoints are critically and theoretically constructed dis cursive positions, not merely perspectives or views that flow from their authors unwittingly because of their biology or location in geographical or other such social locations. (1998, 17)

As far as its impact on the natural sciences can be measured, standpoint theory has been used primarily in two ways—to *describe the biases* present in hypotheses and methods constituted by dominant groups and to *describe the inadequacy* in the standards for achieving objectivity (2004a, 26).

I am interested in pursuing the argument that standpoint theory can be used to *prescribe new practices,* such as research agenda choice for the natural sciences. Despite the controversies surrounding standpoint theory, I am drawn to the promise of an approach whose innovations, as described by Harding, "bring into focus fresh perspectives on some of the most difficult and anxiety—producing dilemmas of our era" (2004b, 1). I am also drawn to the call put forward by standpoint theorists for starting off thought from the lives of marginalized peoples. This idea appeals to me because of the necessary "insider—outsider" sensibilities I have had to hone as a feminist scientist. Although I may have been somewhat isolated in the lab, I reached out to and was embraced by a community of feminist activists and scholars from other disciplines. This sense of community made it possible for me to stay in the sciences but also made me appreciate the importance of starting my scientific thoughts from the lives of marginalized others. While putting forward the notion that it matters *who* the knower is, Lorraine Code notes that this proposition also raises the issue of epistemic relativism. But she argues that epistemic relativism need not be immediately aligned with idiosyncratic or purely subjective thinking. According to Code, "Schemes, practices, and paradigms evolve out of communal projects of inquiry. To sustain viability and authority, they must demonstrate their adequacy in enabling people to negotiate the everyday world and to cope with the decisions, problems, and puzzles they encounter daily" (1991, 3). In theory then, the feminist scientist may be able to reveal herself as a knower and still use standpoint theory as a "communal project of inquiry" in order to negotiate and cope with the decisions of research agenda choice. But why hasn't this been the case? Why hasn't standpoint theory been clearly articulated for the natural sciences? The challenge may be that a transposable model of stand point theory, appropriate for the natural sciences, is yet to be developed. The feminists with whom I had formed a community while conducting scientific research taught me some skills so that I could negotiate my everyday world as a feminist scientist. Most important, they taught me to think about my political location and markers such as gender, race, class, and sexuality while I worked in a reproductive neuroendocrinology lab. I didn't know it then, but looking back now, perhaps I did use a form of standpoint theory to address the technical core of the science I practiced.

In her paper "Why Standpoint Matters" (2004), Alison Wylie outlines a framework for standpoint analysis of scientific practice. She is convinced of the value of feminist standpoint theory but is troubled by the ways in which this theory is commonly reduced by its opponents to a notion of social locations of individuals and to the relativism of identity politics (341). Although Wylie is concerned with the potential for standpoint theory's impact on the *analyses of* scientific practice within the disciplines of science studies and philosophy of science, she also makes a case for the implementation of standpoint theory within the *production of* scientific knowledge itself.

Wylie notes that standpoint theory can exist as a commitment to some form of situated knowledge (343). In this sense, it allows us to "develop a stand point *on* knowledge production, a critical consciousness about the nature of our social location and the differences it makes epistemically" (344). For the feminist scientist, developing an awareness of "how" knowledge is produced is integral to seeing the applicability of standpoint theory for the practice of research agenda choice in the natural sciences. The point Wylie emphasizes however is that standpoint theory must exist without "embracing essential ism or an automatic privilege thesis" (345). In order for standpoint theory to survive and not continually be misread, "It must not be aligned with a thesis of automatic epistemic privilege; standpoint theorists cannot claim that those who occupy particular standpoints (usually subdominant, oppressed, marginal standpoints) automatically know more, or know better, by virtue of their social, political location" (341). In order for standpoint theory to move into the natural sciences and assist in the production of scientific knowledge, it must take the place of dominant approaches that are foundational to the scientific method. However, to put forward the claim that some people (those who are marginalized) know better than others (those who are not marginalized) as a foundational precept of standpoint theory, is too dangerous. In order to make its move into the natural sciences, Wylie's above criteria for standpoint theory is pivotal. Once the feminist scientist acknowledges that as an insider—outsider she knows *differently,* the applicability of standpoint theory for the natural sciences also becomes clear.

Wylie further argues that standpoint theory "offers a framework for under standing how, far from compromising epistemic integrity, certain kinds of diversity (cultural, racial, gender) may significantly enrich scientific inquiry" (339). She suggests that there is value in what the marginalized or insider—outsider standpoint has to offer. The values she refers to include: (1) access to evidence whereby the position of marginality makes one see evidence not normally seen; (2) inferential acuity whereby an individual makes connections between power dynamics; (3) an expanded range of interpretations and explanatory hypotheses for making sense of the evidence; and as a condition for the first three values, (4) critical dissociation from the taken—for—granteds that underpin authoritative forms of knowledge (346). The moment the feminist scientist realizes that her location, relations, and position held within power dynamics give her the required critical consciousness needed to bring a "new angle of vision to bear on old questions and raise new questions for empirical investigation" (349), the hesitations regarding the relevance of standpoint theory in the natural sciences should be put to rest. Wylie's list of values provides the reasons for including standpoint theory in the practice of research agenda choice in the natural sciences. By listing a set of values, Wylie answers the question *why* the marginalized, insider—outsider standpoint is important and can enrich scientific inquiry by producing different knowledges. In fact, her analysis makes it clear as to why we should seek to occupy this standpoint. However, for the feminist scientist who is working in the natural sciences, sitting at her lab bench and scratching her head, I believe the question that remains is *how?*

RECONFIGURING OBJECTIVITY

To address this last question, I am interested in drawing from standpoint theory but moving toward strong objectivity and situated knowledges, and through to agential realism. For the feminist scientist then, who by the very "nature" of her existence qualifies as a marginalized knower, the idea of developing feminist theories such as standpoint theory for the natural sciences should be attractive, but not without one significant hesitation (at the very least). The main hesitation, I believe, in making such a move has to do with reconfiguring her ideas of objectivity. If she bases her practice of research agenda choice on a set of values derived from feminism, can she still be objective?

In order to address this issue, the feminist scientist should be made aware of the fact that her training as a scientist would have required her to think about objectivity in a very limited way, one that is appropriate for producing knowledge specifically through the scientific method. It has to be brought to her attention that the concept of objectivity is much more complex. As has been noted by many historians and philosophers of science, "objectivity is not and has never been a monolithic and immutable concept, at least since the seventeenth century" (Daston 1992, 598). However, the many different forms of objectivity do indeed share one purpose. As Lorraine Daston and Peter Galison note, "Each of the several components of objectivity opposes a distinct form of subjectivity; each is defined by censuring some (by no means all) aspects of the personal. The history of the various forms of objectivity might be told as how, why, and when various forms of subjectivity came to be seen as *dangerously* subjective" (1992, 82). Daston argues that two particular forms of objectivity, namely aperspectival objectivity (1992) and mechanical objectivity (Daston and Galison 1992), have come to play crucial roles in practically every step of modem—day scientific inquiry, but that they did not originally develop within scientific traditions. Rather, Daston suggests that aperspectival objectivity, the idea that one can be a "featureless observer," originated in moral and aesthetic philosophy in the late half of the eighteenth century (1992). As she explains, "Just as the transcendence of the individual viewpoints in deliberation and action seemed a precondition for a just and harmonious society to eighteenth century moralists, so the transcendence of the same in science seemed to some nineteenth—century philosophers a precondition for a coherent scientific community" (1992, 607). Mechanical objectivity, associated with automated or mechanized procedures, also had as its primary function a "morality of self restraint" (Daston and Galison 1992). The goal of this form of objectivity was to remove human emotion or judgment, and therefore any idiosyncrasies from observations made of one's surroundings.

Heather Douglas has also recently suggested that there is no single meaning of objectivity, and has in fact been able to identify eight distinct senses of the concept. She suggests that the senses of objectivity most commonly deployed in scientific research are "manipulable" and "convergent" objectivity (2004, 457). Both of these senses, similar to aperspectival and mechanical objectivity, deal with attempts made by humans to "directly get at the objects" (455) of their surroundings without interfering with them. From her account of the various senses of objectivity, Douglas makes an extremely insightful comment that is pivotal for a feminist reconfiguration of objectivity. She states:

> The complexity of objectivity provides for both its flexibility in usage and the strength of its normative force. There are multiple grounds from which to call for trust of a claim, from which to endorse that claim to others. It should also be clear that the complexity allows room for change. We might decide that some meanings should be dropped (as I think value—free objectivity should be). And we might find that new meanings will be added as our practices change over time. There is no ahistorical fixed ness to objectivity to date; there is little reason to think we are finished developing the term. (468)

As Douglas suggests, by tracing these accounts of objectivity the feminist scientist can realize not only the freedom that comes with complexity but also the possibility for change. In fact, Harding has put forward one of these new meanings of objectivity and developed the term with her idea of 'strong objectivity.' Strong objectivity extends the notion of scientific research to include systematic observations of background beliefs, and also draws attention to ideological assumptions built into scientific research (1991, 149).

Douglas also proposes that there are many locations from which one may gather "trust" for making a claim. The idea of strong objectivity allows us to see that there may be different ways of knowing and not just one adequate standard for knowledge that is gained only through traditional modes of objectivity. More important, it provides the grounds for placing trust in a community of marginalized knowers. For instance, related to the ideas of strong objectivity and the importance of acknowledging a community of knowers, Alan Irwin has described the notion of "citizen science" while bringing to light the importance of local and particular knowledges (1995). He suggests that communities of knowers, as in the case of sustainable development, play a crucial role in "criticizing expert knowledge but also generating forms of knowledge and understanding—in serving as 'living laboratories' in an active as well as passive fashion" (1995, 112). Also in the context of local and participatory knowledge, Frank Fischer has provided an extraordinary example of how a community of knowers can provide the grounds for laying trust in a claim. While discussing the example of the people's science movement in the Indian state of Kerala, Fischer notes that the success of this participatory strategy lies in the fact that it "speaks directly to the concerns of citizen empowerment, democratic theory, and environmental democracy" (2000, 168). The citizens of Kerala designed research projects related to the everyday issues of their own lives. However, the local knowledge that they produced, which was "designed to help less—privileged citizens in their struggles to better understand and confront the realities and choices that shape their own interests and concerns" (145), also informed the type of "expert" scientific knowledge that was produced.

While struggling with my own research agenda choices, I arrived at a need to question my notions of scientific objectivity by way of Donna Haraway's work. It was her ideas on partial vision and more important, my own dilemma of having formed a kinship with a transgenic mouse and her *in vitro* cell line of hypothalamic neurons that brought me to this place. In my simultaneous workings as a lab dweller, transgenic mouse cell line handler, and member of a feminist community of knowers, I had cause to reflect on the meanings of objectivity in deep and intimate ways. Haraway states that "feminist objectivity is about limited location and situated knowledge, not about transcendence and splitting of subject and object. In this way we might become answerable for what we learn how to see" (1991, 190). Haraway's concept of situated knowledges is intimately connected to standpoint theory. Emphasizing location and partial vision, Haraway believes that knowledge can never be universal. However, at the same time, situated knowledges should not be reduced to individual idiosyncrasies or to epistemic relativism. Like standpoint theory, it advances knowledge by helping make visible aspects of nature, science and social relations that are not usually seen or are kept hidden.[6] Objectivity becomes a "positioned rationality" (1991, 196), open to multiple connections. The reason that stand point theory, strong objectivity, and situated knowledges offer potentially mind altering experiences for the feminist scientist is that rather than placing value solely on aperspectival and mechanical objectivity, they invite the engaged and invested investigator, who belongs to a community of knowers, to practice her research agenda choice through a "positioned rationality."

POSITIONED RATIONALITY AND MATERIALITY

Situated knowledges should be acknowledged for not being a theory that simply reduces itself and the matter it touches, into matter made apparent or assembled *only* by the processes of social construction. Rather, situated knowledge positions the feminist scientist in order to engage in a performative (to borrow from Barad's use of the term) account of scientific knowledge production—one with which she is intimately connected and politically concerned.

Indeed, some feminist science studies scholars have previously attempted to incorporate feminist values into science by what has been referred to as social constructivist approaches. While describing social studies of science and technology, David Hess states that "the term 'social constructivism' is often used as a general label for studies that examine how social variables shape the pattern of choices about what research gets done, how it is done, how choices among theories are made in controversies, and the extent to which observations, laws, theories, and other knowledge claims become accepted in wider scientific com munities" (1997, 34). Harding has suggested using the term *co—constructivism* instead to better represent how science and culture "co—evolve." For Harding, the term *constructivism* implies that "pre—existing, fully—formed 'societies' just make up or construct the representations of nature that they want regardless of how the world around them is ordered" (1998, 4). I believe however, that to align research agenda choice in the natural sciences with social constructivist or co—constructivist arguments would be highly problematic. Feminist science studies scholars, such as Haraway (1991), Barad (2003), and Nancy Tuana (2001), have forwarded sharp criticisms of social constructivist arguments by raising difficult questions regarding the issue of materiality, particularly in the case of the natural and physical sciences. Both Barad and Tuana suggest that when it comes to the issue of materiality, the tendency of feminist scholars and philosophers of science has been to easily slip into the scientific realism versus social constructivism debate. Reiterating the tensions and problems of this debate is not feasible in the scope of this essay, nor is it my intention. Suffice to say, for the purposes of developing research agenda choice into a *practice* and putting to proper use our reconfigured conceptions and possibilities for objectivity, feminist interventions into science cannot be sustained *if* these efforts are aligned with either realist or social constructivist arguments. Barad suggests:

> A performative understanding of discursive practices challenges the representationalist belief in the power of words to represent preexisting things. . . . The move toward performative alternatives to representationalism shifts the focus from questions of correspondence between descriptions and reality (for example, do they mirror nature or culture?) to matters *of* practice/doings/ actions. (2003, 802)

Barad's theory of posthumanist performativity offers new possibilities for dealing with matter and bodies in the natural and physical sciences. While describing the problems in linking discursive practices to the materiality of the body and explaining her idea of agential realism, Barad also brings together for us a reconfigured objectivity that fully employs the freedom of complexity. Moving Harding's idea *of* strong objectivity and Haraway's depiction of objectivity as a positioned rationality even further, she states,

> On an agential realist account, it is once again possible to acknowledge nature, the body, and materiality in the fullness of their becoming without resorting to the optics of transparency or opacity, the geometries of absolute exteriority or interiority, and the theorization of the human as either pure cause or pure effect while at the same time remaining resolutely accountable for the role 'we' play in the intertwined practices of knowing and becoming. . . . On an agential realist account of technoscientific practices, the 'knower' does not stand in a relation of absolute externality to the natural world being investigated—there is no such exterior observational point. It is therefore not absolute exteriority that is the condition of possibility for objectivity but rather agential separability—exteriority within phenomena. 'We' are not outside observers of the world." (2002, 812, 828)

Remaining accountable for the roles "we" play is the political part of this practice. Why would the feminist scientist be conducting research if she were not concerned with the questions she was asking or the outcomes of her work? But what happens after the feminist scientist has reconfigured her sense of objectivity and becomes aware that she is embedded within the phenomenon? Can she take advantage of a momentary "agential cut" (815) and use her feminist politics to have a hand in the arrangement of intra—actions for which she will be held accountable? In other words, even though she may realize that she is part of the phenomenon, how can she define and then utilize her standpoint or situatedness in the scientific research that she conducts or research agenda choices she makes? In their own ways, strong objectivity, situated knowledges, and agential realism all help the feminist scientist reconfigure her ideas of objectivity and connect with the scientific research she conducts in more intimate and implicated ways. I think, however, that we may best be able to address the issue of *how* the feminist scientist can localize her politics while she "enacts a local resolution" (815) within a phenomenon by turning to Chela Sandoval's concept of differential consciousness (2000).

MOVING TOWARD DIFFERENTIAL CONSCIOUSNESS: HOPSCOTCHING IN CYBERSPACE

In order to address the issue of how the feminist scientist can engage in scientific inquiry and practice research agenda choice that is informed by the local politics of communities to which she belongs, I believe that we must take a leap of faith, or at least a leap between disciplines. My hope here is to describe the process entailed in taking such a leap, and in doing so, also finally attempt to develop a *semiprescriptive* model of practices that can be used by other feminist scientists to address the problem of research agenda choice. In her work, Chela Sandoval utilizes Haraway's ideas of the cyborg identity and suggests that the cyborg is not just a human(oid) creature born of our technological present and future. Although many theorists treat the idea of the cyborg as a futuristic entity that has evolved through an age of oppositional politics with globalization and technology, Sandoval explains:

> My argument has been that colonized peoples of the Americas have already developed the cyborg skills required for survival under techno—human conditions as a requisite for survival under domination over the last three hundred years. . . . Cyborg consciousness can be understood as the technological embodiment of a particular and specific form of oppositional consciousness that I have elsewhere described as "U.S. third—world feminism." (1995, 408)

Like Sandoval, I interpret Haraway's cyborg as a trope not only for the union of organic material and technological machine but also primarily as a type of consciousness that is based on the lived experiences and skills developed by several types of marginalized people, including the colonized in the United States. In an attempt to integrate "U.S. third—world feminism" into U.S. feminist theory, Sandoval argues that the differential forms of oppositional consciousness do not solely belong to the U.S. third—world feminist but rather is threaded throughout the experience of social marginality and cyborg "politics" (1995; 2004).

The feminist scientist is such a being who exists on the social margins she is a cyborg.[7] Bound to be an insider—outsider—within type of hyphenated creature, cyborg politics may offer her a space for theoretical asylum. We can all agree that in order for the feminist scientist to become a mutated modest witness and survive within the scientific institution, she is required to form a resistance to a number of factors, depending on her sex, gender, race, class, age, and more.[8] She must also learn to resist, for example, the sexist and racist biases that run rampant within the theories, paradigms, and language used to produce scientific knowledge. She is used to "resistance—building." But to be "effective in opposition," the feminist scientist must also have a way to *express* her "differential consciousness" in the space where she resists.[9] What I would like to suggest here is that while suspended in an "agential cut" (Barad 2003, 815), the expression of her differential consciousness can guide the feminist scientist through the practice of research agenda choice, allowing her to politicize her engagement within the processes of the scientific method and to embed her knowledge practices within a community of marginalized knowers.

Sandoval argues that U.S. third—world feminism presents a new form of "historical consciousness" that developed just outside of the dominant feminist theory that emerged in the 1970s (2004, 195). In this consciousness, "no enactment is privileged over any other, and the recognition that each site is as potentially effective in opposition as any other makes possible another mode of consciousness" (200). Her aim is to harness the collective energies of people seeking "affective liberatory stances in relation to the dominant social order" (2000, 43–44). Sandoval states,

> The idea here, that the citizen—subject can learn to identify, develop, and control the means of ideology, that is, marshal the knowledge necessary to "break with ideology" while at the same time *also* speaking in, and from within, ideology, is an idea that lays the philosophical foundations enabling us to make the vital connections between the seemingly disparate social and political aims. . . . Differential consciousness is the expression of the new subject position called for by Althusser—it permits functioning within, yet beyond the demands of dominant ideology. (2000, 44)

Sandoval is suggesting that one can reside within an "ideology" in order to change that ideology. This is where the feminist scientist is at an advantage. As an insider, she has intimate knowledge of the traditional scientific method and the dominant ideologies influencing her research agenda choice. But as Sandoval suggests, in order to change the dominant social order created by traditional conceptions of objectivity and scientific method, and go on to create different scientific knowledge by "asking different questions," the feminist scientist must learn to *identify, develop,* and *control* the means of ideology. Indeed, Sandoval has named a "set of processes, procedures, and technologies for decolonizing the imagination as the methodology of the oppressed" (2000, 69).

Standpoint theory and situated knowledges help us recognize our place within dominant ideologies. Sandoval's methodology of the oppressed takes this further and shows us how to *develop* and *control* these ideologies. As is the case with most feminist theory, however, the insights and approaches of the methodology of the oppressed readily translate into new research agendas for feminists residing within the humanities and social sciences, while remaining an abstract notion (if at all) to feminists within the natural sciences. For the remaining portion of this paper, I will attempt to begin this process—to move the feminist scientist from a state of anxiety to a place of mutant modest witnessing by demonstrating the applicability of the methodology of the oppressed in the practice of research agenda choice.

VECTORS, TRANSFECTIONS, AND TRANSFORMATIONS

Sandoval has described the methodology of the oppressed as consisting of five components that she alternately refers to as "technologies": (1) semiology; (2) deconstruction; (3) meta—ideologizing; (4) democratics; and (5) differential movement (1995, 409). Put together, these technologies are seen as a form of cyborg resistance. There are two main reasons for choosing the methodology of the oppressed for my own work. First, I think that this methodology can be seen as an intricate extension of standpoint theory and situated knowledges, and is both logical and creative in its design. Because of both its structure and flexibility, it can be used to develop a semiprescriptive model of practices for the feminist scientist in the natural sciences. The second argument for using the methodology of the oppressed in my project is that it is simply too tempting not to. Sandoval is fond of using technological metaphors, such as vectors, for the description of very real social maneuvers. I appreciate this willingness to move across disciplines, across liberating causes, and across cyborg—inhabited spaces. Indeed, she has already started the experiment from her location in the labs of the humanities and social sciences. But in order to make this political practice more accessible to the feminist scientist in the labs of the natural sciences, I would like to conduct a technology—transfer of sorts. I would like to mutate Sandoval's mathematical vectors into biological vectors, also known as plasmids. Biological vectors are used to introduce "new" information into an organism. This molecular biology—based technology is referred to as *transfection*. For the remainder of this paper, I share a series of transfections that introduces the methodology of the oppressed into the natural sciences. My hope is to illustrate the relevance of this feminist theory to the feminist scientist and provide her with an example of how this political practice can be used to conduct her research agenda choice.

TRANSFECTION 1: DIFFERENTIAL MOVEMENT

For Sandoval, differential movement is a "split consciousness" where one is able to "shuttle between realities" and "see from the dominant viewpoint as well as one's own" (2000, 83). By shuttling between realities, a hyphenated creature is able *co* go back and forth from the inside to the outside, and by doing this, even exist in an "interstitial site or third space" (2000, 83). As described earlier, this third space, or cyborg—space, is a familiar site for the feminist scientist. Engaging in differential movement will likely be dizzying for the feminist scientist in the beginning, but acknowledging a "split consciousness" is a necessary first step in developing the practice of research agenda choice. Therefore, the first mutation to Sandoval's methodology of the oppressed is to bring her last technology, the vector of differential movement, upfront in a feminist practice of research agenda choice. If the feminist scientist is able to appreciate the relevance of feminist theory for the natural sciences and reformulate her ideas of objectivity, she should also have come to the realization that her position as an insider outsider allows her to see from the dominant viewpoint as well as her own. This split consciousness allows or even forces her to look at science differently than her nonfeminist peers. By looking at science differently, I mean to suggest, for example, that she may be concerned with what counts as knowledge and how knowledge is produced. She may be concerned about the theories and paradigms used to organize and conduct her experiments. She may also be concerned with the techniques used to conduct research, gather evidence, and put her findings into scientific language. Any one or all of the concerns above may present a dilemma for the feminist scientist and send her whirling. But at the same time, these concerns present opportunities for practicing research agenda choice as a political action and from a position of differential consciousness. In fact, it is her ability to 6rst articulate a dilemma in the science that she practices while simultaneously seeing from the dominant scientific viewpoint that ultimately stabilizes her in "differential movement," providing her with the impetus to "ask different questions."

In my case, for instance, the very first dilemma I faced in my Ph.D. work was regarding the use of animals in my research. In reproductive biology research, it is unusual to conduct experiments without using what is referred to as "animal models." I knew that killing and conducting research on animals was going to be expected of me as a graduate student. And so, when the question came whether I had done animal work before, I responded that I hadn't and in fact planned on never conducting *in vivo* research to do my scientific work. This dilemma produced a difficult moment in my Ph.D. interview and in the years that followed. Fortunately, my supervisor was supportive. She allowed me to use an *in vitro* neuronal cell line to conduct my work and never pressured me into doing animal work. But at every step of the way, including my Ph.D. defense, I had to defend myself to other scientists for not conducting any of my research on "whole" animals. In retrospect, I now see that my decision not to conduct animal work was not in and of itself what made my project feminist, but was in fact an example of my practice of research agenda choice. I was making a choice between using biological theories that support *in vivo* research versus those that support *in vitro* research. I was also making a theoretical choice between the materials of my research, which directly influenced the methods and technologies I used. Instead of using cages and an animal facility to house mice, I used plastic Petri dishes and a 37°C incubator to grow neuronal cells. My decision to use an *in vitro* model had its own problems, but ultimately, it was a very important decision that stabilized me in my own differential movement. Articulating my dilemma while simultaneously seeing from the dominant scientific tradition—at least enough to defend my decision to conduct only *in vitro* research to other scientists—allowed me to continue contributing to the production of scientific knowledge.

TRANSFECTION 2: DEMOCRATICS

I interpret Sandoval's technology of democratics to be the driving force, the inspiration, and the motivation for wanting change. Sandoval notes that such authors as Frantz Fanon and Patricia Hill Collins have referred to this technology as a type of politics that demands for "egalitarian social relations" (2000, 83). The demand for "egalitarian social relations" also applies to the feminist scientist, who like all other feminists is concerned with the "redistribution of power" so as to eliminate injustices based on differences coded under categories of race, gender, sex, age, class, and others (112). In the case of the feminist scientist in the natural sciences, she would be concerned with practicing research agenda choice in such a way as to eliminate injustices that result from decisions regarding which scientific knowledge gets produced, the ways in which this scientific knowledge is produced, and whose lives are affected by this knowledge, both in its production and consumption. For instance, she may want to practice her research agenda choice so as not to base her research on the naturalization of inequities that may be rooted in biological determinism.

However, to develop a strategy for the "redistribution of power" in the natural sciences, the feminist scientist must first have a grasp of the "distribution of power" in her specific scientific setting. Her education and training within the dominant traditions and institutions of science would have provided her with this insight. In fact, it is the experience of knowing the distribution and dynamics of power that informs her as to *what needs to change* in this distribution. This may include changes in the ways an individual researcher interacts with other researchers within the intimate settings of her own lab, the ways in which experimental materials or subjects are handled, the language used to represent scientific findings, or even on a different scale, the inequities within science that are produced at an institutional level such as gender disparities in hiring practices. She may, however, have to choose the battles for egalitarian relationships in which to invest her energies—step–by–step and perhaps even day by day.

In order to briefly illustrate how the feminist scientist may implement "democratics" into the practice of research agenda choice, take for instance once again, the choice between conducting in *vivo* and in *vitro* research. A feminist scientist, concerned with the "redistribution of power" may be concerned with eliminating injustices based on perceived differences established through not only the categories of race, class, sex, and gender and so forth, but also that of *species*. My exposure to animal facilities, to some scientists who seemed to draw pleasure from killing animals, and to the language of science which misleadingly referred to the killing of animals as "sacrifice"—as if the animals willingly gave their lives for research purposes—led me to the decision to use a cell line instead of animals. I chose to put my energies toward a specific redistribution of power by finding alternate ways to continue my scientific research. But my decision to redistribute power in this way was not without its own apprehensions. Starting from the mice that had to be killed years before I started my Ph.D. work in order to develop the *in vitro* cell line model that I used, to the principles of reductionism and targeted mutagenesis used to create the cell line in the first place, my demand for one egalitarian social relation led to an awareness of different but related tensions that I would later try to address within my scientific research.

TRANSFECTION 3: SEMIOTICS

This technology has already been dealt with to some degree while discussing Haraway's theory of situated knowledges. In the case of the methodology of the oppressed, semiotics involves learning the "science of signs in culture" (Sandoval 2000, 82) and "recognizing the dominant social reality as an *interested* construction" (86). Drawing from the work of Frantz Fanon and Roland Barthes, Sandoval states that the "science of semiology," so named by Barthes, is a method for freeing consciousness from the domination of social order and identifying the grounds for coalition among the "subordinated" (88). She goes on to say that a "commitment to sign reading emerges as a means of survival" (86). For the feminist scientist who has articulated her anxiety—producing dilemma(s) through the technology of *differential movement,* and is formulating her ideas on the distribution of power in the technology of *democratics,* the next step involves transforming her relationship within the science that she practices. She begins this transformation with semiotics, the process of sign reading.

For example, part of the dominant social reality held by scientists in reproductive biology research is a shared belief in the validity of using *in vivo* animal models. The "animal model" is a *sign* that exists in the culture of scientific enterprise. Haraway has already discussed the sign of the oncomouse at great length (1997). As the term "model" connotes, these animals are used for the processes of meaning making. But not only are they used for the processes of meaning making, they are in some cases entirely constructed, literally and figuratively for this purpose, particularly in the case of designing transgenic animal models for the study of disease. Scientists have come to rely on these animals—these *interested constructions—for* their access to scientific knowledge and breakthroughs. These transgenic animal models simultaneously represent that which we have no previous knowledge of and therefore must become aware, that which is difficult to interpret and therefore requires endless study, and that which we as scientists can control and create—answers to our own riddles. Realizing the construction of this social reality and the contradictions that emerge can free the feminist scientist from following along with this particular dominant social order.

TRANSFECTION 4: DECONSTRUCTION

Directly connected to the technology of semiotics is the technology of "deconstruction," which Sandoval defines as "the process of challenging dominant ideological forms" (2000, 83). The realization that "ideology is a pattern" is integral to this technology. Sandoval's vector of deconstruction aims to "un form" dominant social ideologies. To deconstruct dominant social ideologies, however, the feminist scientist, being a novice sign—reader, must once again go to the beginning and bring form to that which she must un—form. For example, she must start seeing patterns in the ideologies or paradigms used to create scientific knowledge. She must "tease open to show the sticky economic, technical, political, organic, historical, mythic, and textual threads," which wound together make the "knots of knowledge making practices" (Haraway 1997, 68) and thereby bring to light the socially produced consciousness of her surroundings. Deconstruction in this sense then is the practice of revealing patterns of ideology by making connections not normally made, or in fact constructing new and alternate connections while located within the margins. For the feminist scientist, the fourth step of a feminist practice of research agenda choice involves bringing to light the hidden, but ever present patterns of ideology that influence both the scientific paradigms and nonscientific beliefs on which she herself relies to produce scientific knowledge.

In my example, the sign of the animal model represents a dominant ideological form. Most of the scientists with whom I have worked accept that one should never rely completely on in *vitro* work as using an in *vivo* animal model interestingly enough has come to represent a "(w)holistic" approach to conducting reproductive biology research. It is conveniently put aside that inserting genes into animal embryos in order to create transgenic animal models, keeping animals locked up in cages, or removing their gonads and pumping them up with hormones may be counterintuitive to the idea of working with "whole" animals. In fact, this is one rare instance (and only because it is convenient) when most scientists will take a stance against reductionism. *In vivo* research or animal model work is a dominant ideological form in this scientific research because there are knots of knowledge making practices that have supported it in making it so. In thinking about transgenic animal model work, it is not a difficult task to see the patterns in this dominant ideology, starting from the use *of* subordinated bodies in medical and scientific research, where the bodily histories *of* animals and women have so often converged, to the lucrative economic potential of a circular ideology, whereby the scientist must constantly create and destroy the "object" of study. These hidden patterns *of* ideology easily unwind in the case of transgenic animals and animal models more generally to bring to light the socially produced consciousness under which most scientists in this field operate.

TRANSFECTION 5: META—IDEOLOGIZING

The last mutation to the methodology of the oppressed places meta—ideologizing in the final position in the practice of research agenda choice. As stated earlier, one reason for choosing the methodology of the oppressed is that it provides a semi-prescriptive analysis and practical framework for change. According to Sandoval, the technology of meta—ideologizing is the "operation of appropriating dominant ideological forms, and using them whole in order to transform them," which "is absolutely necessary for making purposeful interventions in social reality" (2000, 83). The feminist scientist is at an advantage as an insider—outsider and has the opportunity to use this technology to intervene in the production of scientific knowledge by asking different questions." She is perfectly poised to meta—ideologize. She has the potential through new scientific discoveries "either [to] display the original dominant ideology as naive—and no longer natural—or to reveal, transform, or disempower its signification in some other way" (109). With the goal of revealing, transforming, and/or disempowering dominant forms of scientific ideology, meta—ideologizing comprises the last step in the practice of research agenda choice.

One last time, let us consider the decision to conduct *in vitro* versus *in vivo* research and what this may mean for a feminist scientist in terms of practicing research agenda choice as a political action. As a foundational tenet of modern science, reductionism—the idea that every complex biological organism can be understood by examining individual components and simple mechanisms—is perhaps one of the most dominant ideological forms that a feminist scientist will encounter. However, in my own research in reproductive biology, I was concerned with another dominant ideology that although related to a great extent to the ideology of reductionism, also specifically framed parts of the female body involved in reproduction in a hierarchical relationship. My belief was and still is that much of the scientific research that affects the reproductive and sexual health of millions of women around the world is deeply influenced by this dominant ideology that places the brain in control of the pituitary gland and gonads. In my scientific work, I decided to use molecular biology techniques on an *in vitro* cell line, which was itself produced through the principles of reductionism, to counter this hierarchical ideology. As an insider—outsider within the dominant traditions of science, my double serving of reductionism was in fact driven by my desire to intervene in a scientific construction that directly affected the lives of women who use contraceptives and other hormone mediated reproductive technologies. I used the principles of reductionism in order to develop a new feminist practice. By using reductionism in the form of conducting molecular biology as well as *in vitro* research, I attempted to appropriate this dominant ideology in order to create new scientific knowledge and to *speak to* the very scientists who use reductionism to develop the hierarchical model of reproductive biology in the first place. It can be said that I "used" reductionism to try to "reveal, transform, and disempower" the signification of reductionism in another form. The research agenda choice to conduct *in vitro* research may therefore be seen as a political maneuver, one that has the potential to function at the level of meta—ideologizing.

THE PROMISE OF NEW FEMINIST TECHNOLOGIES

I have attempted in this paper to speak to a few different audiences. I am of course concerned with formulating strategies that the feminist scientist can use in her everyday scientific activities. But by aligning dilemmas, research agenda choice and the ability to "ask different questions" with feminist *practices,* I have also attempted to create a conversation among feminist scientists, feminist science studies scholars, and philosophers of science who, in my estimation, are all concerned with these issues, even if for distinct reasons. As Rouse has stated while defining his idea of practice:

> This normative conception of practices . . . changes how one should think about the semantic, epistemic, and political dimensions of scientific practices, and about the ways they are interconnected. . . . Philosophical reflection upon practices conceived in this way must critically engage with the practices themselves, in ways that are also accountable to what is at issue and at stake in those practices. (2002, 162)

This is where the creation and use of *new feminist technologies* as practices become pivotal. Technology may be evil, but technological illiteracy is worse. Calling upon technologies such as vectors and transfections in order to describe the political maneuvers of a practice *is* a political maneuver. It is a way to engage critically with the scientific practices themselves. If there is to be an ongoing interdisciplinary conversation on practices between the audiences above, all parties concerned may have to tolerate metaphors, analogies, and perhaps even a little bit of humor.

I have chosen somewhat of a rhizomatic approach to map connections among standpoint theory, strong objectivity, situated knowledges, agential real ism, and the methodology of the oppressed, in order to develop what I think may *serve* as a series of loosely defined prescriptions and a suitable framework for the practice of research agenda choice in the natural sciences. I have also attempted to reach out as a feminist scientist and follow the cues for transposing *differential consciousness* into the natural sciences. More specifically, I have demonstrated how the methodology of the oppressed can be used to transform the traditional scientific practices—from the inside.

Drawing from the strengths of an insider—outsider positionality, a feminist *practice* of research agenda choice is not meant to completely discard or erase all of the traditional activities of scientific inquiry, but rather to provide the feminist scientist with the necessary tools to produce interruptions or positive disruptions in the processes of scientific knowledge making. It is a practice that can transform anxiety—producing dilemmas into the ability to "ask different questions." This ability ultimately translates into her power to produce *different* scientific knowledge, which at the end of the day, is the goal for every feminist scientist.

NOTES

I am grateful to the participants of the Feminist Epistemologies, Methodologies, Meta physics, and Science Studies (FEMMSS) conference at the University of Washington for helping me formulate ideas for this paper and to the participants of the Philosophy of Social Sciences Roundtable at the University of California, Santa *Cruz,* for commenting on an earlier draft. I would also like to thank *Hypatia's* reviewers for their generosity as academic mentors and for providing extremely thoughtful criticisms.

1. "Asking different questions" is a phrase feminist philosophers of science and feminist scientists commonly use while trying to describe the ways in which feminism can intervene in the processes of science. I first came across this expression while watching the film *Asking Different Questions: Women in Science* (1996).
2. I am grateful to my Ph.D. supervisor Denise Belsham for providing me the opportunity to participate in these research projects and to benefit from her expertise in reproductive neuroendocrinology and molecular biology.
3. In her influential work *The Woman in the Body* (1987), Martin critiqued scientific theories used to study menstruation and menopause. She made the observation that a common paradigm used by scientists to conceptualize the female hypothalamic—pituitary gonadal (HPG) axis was that of a hierarchy, with a region of the brain known as the hypothalamus in control (41).
4. I borrow the phrase *anxiety—producing dilemma* from Harding (2004b, 1).
5. I am drawing here from Barad's use of the term *phenomena* to mean "the ontological inseparability of agentially intra—acting 'components.' That is, phenomena are ontologically primitive relations—relations without preexisting relata" (2003, 815).
6. While describing Haraway's theory of situated knowledges, Campbell notes that "situated knowledges then, offers a strategy for developing a feminist model of reflexive science studies but ultimately does not develop that model. Despite its promise, "Situated Knowledges" does not answer the science question in feminism" (2004, 173). I would disagree with Campbell's assessment of the progress made by Haraway in developing and delivering a feminist model relevant to the sciences. I see situated knowledges and Haraway's conception of the technoscientific body as stem cells and sticky threads as a "model in progress" that was not necessarily designed with the intent of providing *an* answer—or the answer. Rather they serve as means to *finding* answers and toward developing feminist practices. Although it may not have "answered" the science question in feminism, I believe that situated knowledges addressed the science question in feminism in a way that no other previous attempts at theorizing feminist scientific practices had succeeded in doing.
7. I am aware that Haraway, in her own words, has "gone to the dogs." In her recent work, *The Companion Species Manifesto* (2003), Haraway moves away from her use of the cyborg, explaining, "I have come to see cyborgs as junior siblings in the much bigger, queer family of companion species" (11), and that cyborgs can "no longer do the work of a proper herding dog to gather up the threads needed for critical inquiry" (4).

   I choose, however, to continue using this queer sib as a trope for the feminist scientist. At this point in my project, I may be more successful in bringing feminist theory to the feminist scientist who is isolated in her lab by reaching out with a cyborg appendage rather than a paw. Once they're in, I am all for things going to the dogs.
8. Haraway has created the figure of the mutated modest witness to help us imagine constructive feminist engagements within the worlds of science and technology. She explains that her

modest witness, instead of being "simply oppositional," is by necessity implicated in the "net of stories, agencies, and instruments that constitute technoscience." The task of the mutated modest witness is to "learn and practice the mixed literacies and differential consciousness that are more faithful to the way the world works" (1997, 3). By moving from Haraway to Sandoval, my hope is to tease out and further explain the relevance of practicing differential consciousness to the feminist scientist who is living in the domains of the natural sciences. She is already an implicated modest witness, but her mutation is required in order to ask different questions successfully.

9. *Resistance building, effective in opposition,* and *differential consciousness* are all terms used by Sandoval (2000).

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CHAPTER 15

"Keep Life Simple": Body/Technology Relationships in Racialized Global Contexts

Chikako Takeshita

After the birth of my second child in 2005, I had my second IUD inserted. This time it was a Mirena, which releases a synthetic progestin, levonorgestrel, from an intrauterine capsule and prevents pregnancy for five years without replacement. The device is one of the most effective contraceptive methods, comparable to surgical sterilization. In clinical trials, the pregnancy rate was less than I percent, and fertility returned to normal levels after users discontinued the device. The ParaGard, the other IUD product available in the United States, is a copper-bearing IUD that lasts ten years. Although the two types of devices have similar contraceptive efficacy and reversibility, users of the two different devices typically experience significantly different side effects. Whereas the copper tends to increase menstrual bleeding and cramping, the levonorgestral-releasing IUD (LNG-IUD) reduces them. Clinical trials found that menstrual bleeding completely stops in 20 percent of Mirena users, a condition known as amenorrhea.

Several months after the Mirena insertion, I developed amenorrhea, which I embraced. As someone not particularly attached to menstruation as something that defines my femininity, I greatly appreciated not having to endure the inconveniences and physical discomfort that accompanied the monthly period. As an environmentalist, I was pleased not to have to produce any more tampon and sanitary napkin trash. This was a wonderfully liberating corporeal experience.[1] Mirena users who post their experience on the Internet often echo my sentiment. One thirty-five-year-old woman, for instance, wrote, "I LOVE my Mirena. . . . Mirena has made me feel free, not moody, no pain, no period."[2] Internet postings also reveal, however, that a significant number of women are experiencing undesirable side effects such as weight gain, mood swings, and loss of libido. These symptoms were not frequently observed in clinical trials but nevertheless are real and bothersome for these women.[3] Still other postings indicate that many women who are on Mirena after having tried other contraceptive methods are satisfied with the device. Sometimes Internet blogs mention the women's gynecologists, who are equally enthusiastic about this highly effective contraceptive. These doctors believe the device is safe and free of adverse side effects, and they view the altered menstrual pattern in a favorable light.

Mirena is marketed successfully within a pharmaceutical-marketing rubric of "lifestyle drugs." In other words, when a woman has a positive Mirena experience, the device is functioning as a pharmaceutical product that "promise[s] a refashioning of the material body with transformative life-enhancing results."[4] In recent years, pharmacological therapies claiming to treat baldness, sleep difficulties, excessive weight gain, mild depression, general aging, and sexual performance have become increasingly popular. These medications are not treatments for serious diseases. Rather, they treat or prevent various mild conditions that are often labeled a "problem." Taking a drug not only resolves the problem, but may also enhance the individual's life experience and productivity. For instance, low libido is now considered to be a health issue that can be fixed by medication for erectile dysfunction, which could simultaneously contribute to a man's overall well-being by increasing his sexual appetite, restoring what he perceives to be his manliness, and improving his outlook on life.[5] Similarly, decreased productivity at work might be treated with antidepressants, which are presumed to lift one's mood and help get through tasks more easily.[6]

Menstrual regulation and suppression medications that have become popular are yet another type of lifestyle drug. Feminist scholars Laura Mamo and Jennifer Fosket show that menstruation is cast as inconvenient, undesirable, and even unnatural in the marketing campaigns of Seasonale, the first oral contraceptive to reduce the number of menstrual periods from twelve to four a year. Various similar products are now being offered as a seemingly natural solution to what is sometimes viewed as a nagging female problem. By changing the material body, lifestyle drugs transform life from the inside out. Direct marketing to consumers of pharmaceutical products communicate this idea by presenting images of people whose lives are positively transformed by the medication.

When Mirena appeared on the TV screen around 2007, the commercial only briefly mentioned shorter, lighter periods as a common occurrence in users. Yet because the cultural narrative that renders menstrual suppression a positive lifestyle choice had already been solidified with period-reducing oral contraceptives, viewers were prepared to accept and appreciate the device's major side effect as a bodily enhancement. The advertisement, which shows a mother of three young boys appreciating her freedom from having to worry about birth control, conveys two additional ways the device improves women's lives through transforming the body. First, the ad suggests that the easy-to-use long-acting contraceptive enables a woman to "keep life simple." Second, it sends the message that retaining the option to have more children is another lifestyle choice that Mirena, a reversible method, allows a woman to make. To this end, the clip announces that the mother has "changed her mind" and concludes with a picture of her holding an adorable new baby girl standing with the rest of her happy upper-middle-class suburban white family.

To an average TV watcher, Mirena appears to be a new contraceptive product with unique features that promise to make a user's life better. The representation of the lifestyle IUD, however, obscures the history of the device and the broad spectrum of biopolitical interests that its development has engaged along the way. This essay examines the making of Mirena, while revealing the behind-the-scenes aspects of this now increasingly popular contraceptive method and reconstructs the historical paths that produced this device. This activity, which I call *diffraction* after Donna Haraway's optical metaphor, shows how contemporary IUDs came to be, while simultaneously grasping the multiple meanings the device now embodies. The historical trajectories that made Mirena and the copper-bearing IUD ParaGard what they are today involved creating and reinforcing inequities among women of different races, classes, nationalities, ages, and levels of modernity. By tracking the backstories of how Mirena is represented, marketed, and embodied in the global North, this essay brings into relief the transnational and racial political economies of women's bodies, health, and reproductive interests.

FROM A POPULATION CONTROL TOOL TO A COMMERCIAL PRODUCT

The period-free IUD that some of us love was created over the course of three decades. The first study to look at the effect of intrauterine administration of hormones was supported by the Ford Foundation and published in the journal *Fertility and Sterility* in 1970.[7] The Chicago researchers who inserted progesterone-releasing capsules into the womb observed changes in the uterine lining similar to those induced by oral contraceptives. They concluded that locally administering a hormonal substance in the uterus could be a way to increase the contraceptive effectiveness of IUDs.

Using discriminatory language common at the time to describe ideal IUD users, the authors related their study to the need for population control. According to them, women "in the less advanced countries" who lack "sophistication and motivation" were good candidates for this method because it achieves prolonged contraception "without special patient cooperation."[8] Early IUD studies presumed that women of the global South were not self-motivated to contracept, which justified the need for this new birth control method that could be imposed on women who, according to the population control advocates, were otherwise unwilling to limit their fertility or incapable of doing so. Studies of hormone-releasing IUDs initially drew their justification from a perceived need to increase reproductive control over former colonial subjects.

The primary goal of adding progesterone to an IUD was to decrease pregnancy rates of the existing plastic devices, which ranged from 2.3 to 10.8 per 100 women in one year. The researchers were pleased to find that no one wearing the progesterone-releasing device got pregnant during the study. The hormonal compound available at the time, however, lasted for only about twelve weeks, making the life span of the device "too short . . . to be meaningfully used in population control."[9] Nevertheless, the authors decided that what they had observed showed enough promise to suggest further development of this method.

THE NEXT-GENERATION IUD

Research on hormone-releasing IUDs started at a time when developers were becoming frustrated with the performance of plastic IUDs. The effort to improve the inert devices by tinkering with their physical configurations seemed to take them nowhere. In the late 1960s, developers began investigating bioactive substances that could be added to IUDs to simultaneously increase contraceptive efficacy, reduce expulsion rates, and decrease bleeding and pain. The Population Council started developing copper-bearing devices with this intention in 1969. Other bioactive compounds such as estrogen and antiprogestin substances were also experimentally added to intrauterine devices, but these did not yield promising results.

This was also a time when the safety of the oral contraceptives was starting to be publicly questioned. It was becoming apparent that hormones from the oral contraceptive entering the bloodstream could cause severe headache, breast tenderness, and mood change, as well as rare but serious adverse consequences such as a fatal blood clot. This realization boosted the idea of administering hormones locally in the uterus, which theoretically would avoid systemic hormonal side effects. Within a few years, the authors of the 1970 study managed to develop a device that lasted six months. After testing it for twelve months, they concluded that its contraceptive effect was very good, although it needed to last longer for population management.[10] By the mid-1970s, a California-based company independently developed and started marketing a one-year progesterone-releasing IUD they called Progestasert, which stayed on the market on a small scale for the next couple of decades.[11]

The development of a multiyear hormone-releasing IUD, however, had to wait for the discovery of a synthetic progestin with high potency per unit weight that can be released slowly over many years. Such a compound emerged several years later from the Population Council's work to develop a hormone-releasing subdermal contraceptive implant. Sheldon Segal recounts his excitement when the idea of the "under-the-skin pill" came to him, and he experimentally implanted capsules filled with various hormones into rats in the council's laboratory.[12] Soon after, in 1970, the Population Council established the International Committee for Contraception Research (ICCR) to facilitate collaboration among a team of international scientists. The committee embarked on the development of the subdermal contraceptive with Elsimar Coutinho of Brazil as the head of the project.[13] After testing no fewer than ten compounds and a number of different capsules and rods, the research team selected levonorgestrel as the most promising progestin and ultimately produced the contraceptive method known as the Norplant.[14]

Another ICCR scientist, Tapani Luukkainen of Finland, led the development of the levonorgestrel-releasing IUD, and after more than a decade of testing to determine the appropriate dosage through a series of clinical trials, he introduced it in Finland in 1990 with the brand name Levonova.[15] Rebranded as Mirena in some other countries, the device was inserted in approximately 1 million women around the globe before it received approval from the U.S. Food and Drug Administration (FDA) in 2000 and started being sold to American women in 2001.

THE NORPLANT SAGA

Ironically, the Norplant, to which Mirena owed its hormonal compound, had been virtually withdrawn from the American market by 2001. The social reception of the Norplant after its introduction in the United States in 1990 was "mired in controversy, suspicion, and even ethnic conflicts" due to socially problematic applications of the device.[16] The idea of the under-the-skin pill was conceived when the Population Council was seeking a superior long-acting reversible contraceptive after it had come to realize that the IUD would not fulfill its expectation to become the one-size-fits-all solution for the problem of excess fertility in the global South. Norplant was in essence the next-generation imposable method and carried with it all of the problematic assumptions about controlling what the council saw as "excessively fertile" women's bodies. The biopolitical quality embedded in the implant technology was immediately expressed in the applications of Norplant in the United States. Within a few years, lawmakers proposed more than forty bills that either mandated Norplant use for women who received government assistance or targeted women who are poor, convicted, or addicted to drug and alcohol in order to prevent them from having children.[17] Norplant was also offered to poor inner-city adolescents at no cost in school-based clinics in Baltimore. The contraceptive implant was also distributed to the Native American population.[18] All of these applications were met with suspicion due to the "deep worries about discrimination in the United States on the basis of class, race, and gender."[19]

Some Norplant users also experienced undesirable and often unbearable hormonal side effects, including headache, acne, nausea, depression, scalp hair loss, weight gain, and irregular or heavy vaginal bleeding.[20] Yet these users could not easily discontinue the medication; they had to have a trained health care provider remove the Norplant, a painful procedure that involves making incisions in the arm, and often had to pay for this as well. Thousands of women filed lawsuits against its distributor, Wyeth-Ayerst Pharmaceuticals, claiming that the company failed to properly inform users about removal problems and adverse side effects. Most of the lawsuits were settled out of court or dismissed, and the company never lost a suit. Wyeth nevertheless suspended Norplant sales in the United States in 2000 after recalling a defective batch of the product and eventually withdrew the product completely from the American market.

Although Mirena is also a long-acting provider-dependent method using the same progestin as Norplant and both were developed by many of the same researchers, it has avoided being accused of discriminatory applications and becoming a target of concerted efforts to sue the provider. In part, Mirena has been helped by the timing of its release, which came after lessons were learned from the Norplant downfall. The Norplant controversy led to a public debate concerning moral and policy challenges of long-acting birth control methods. The Hastings Center, a nonpartisan research institute specializing in bioethics and public policy, assembled a task force that issued a report in 1995 on the ethics of long-term contraceptives.[21] Most members of the task force explicitly stated that compulsory use of contraceptives is unjustified for welfare recipients and generally in most other circumstances. Controversies and ethical debates around Norplant most likely discouraged lawmakers to recommend any new policies that involved long-term contraceptive methods. Mirena has thus far not become a target of public outrage, which has helped the device maintain a neutral image. The positive acceptance of Mirena also can be attributed to the fact that by 2001, the tragic incidents around the Dalkon Shield in the 1970s had been forgotten and a new generation of physicians and women was ready for a new contraceptive method.

Mirena's manufacturer has also kept a low profile, advertising the product in parenting magazines with images of content-looking well-to-do families and staying away from the population traditionally targeted in these problematic applications of imposable methods. In constructing an attractive product, the long-lasting effect of the device, which was problematized in the context of coerced contraception, has been recast as convenience with the assurance that the device can be removed if the woman changes her mind. The device's association with population control has been virtually wiped out by the clean and liberating image created by its TV commercial.

But this transformation did not occur automatically or overnight. Changes in the bleeding pattern caused by LNG-IUD took the device down a meandering path that necessitated sorting out the meaning of this side effect.

THE PROBLEM OF MENSTRUAL BLEEDING

To discuss the issue of bleeding in IUD users, it is necessary to start back once again in the late 1960s when researchers admitted that they had failed to develop an ideal plastic device. They conceded that design innovation efforts focused too much on increasing the contraceptive efficacy and uterine retention and not enough on reducing side effects. Pain and bleeding resulted in so many discontinuations of the contraceptive method that the U.S. Agency for International Development (USAID) eventually decided to prioritize funding for research on a "bloodless, comfortable IUD."[22] Incidentally, the 1970 study had found that intrauterine hormone capsules decreased uterine contractions and vaginal bleeding. IUD researchers hence characterized progesterone as a "uterine tranquilizer" and hoped that future hormone-releasing IUDs would improve the overall efficacy of the contraceptive method by reducing cramping, pain, and bleeding.[23]

Although researchers knew these side effects were an obstacle to broader acceptance of IUDs, data to understand the problem in detail were scarce. Complaints of pain and discomfort were often characterized as psychological, and physicians dismissed them as a normal part of using the device for which certain women had low tolerance thresholds. The Cooperative Statistical Program (CSP), the multilocation large-scale statistical program that took place between 1963 and 1968 and validated the contraceptive efficacy of the IUD, reflects a lack of emphasis on women's subjective experiences. The study simply bundled "bleeding and/or pain" as a single category of reason for IUD removal.[24] It did not provide information on whether the patient requested removal because she could not tolerate menstrual cramping, had debilitating abdominal or back pain, experienced too much bleeding, found her period unacceptably prolonged, had too much midcycle spotting, or experienced some combination of symptoms. This made it impossible to analyze the relationship between side effects and removal in detail.

Because pain is difficult to measure objectively, systematic research on pain with IUD use is almost nonexistent. Blood loss, however, is quantifiable and is a source of health concern; hence, some researchers turned to measuring it in their studies. Studies found that, on average, women lose about 35 milliliters of blood during a menstrual period. Common plastic IUDs, which were larger in size and therefore more irritating to the uterus than smaller copper-bearing IUDs, increased the blood loss by 20 to 50 milliliters. The smaller copper-bearing IUDs increased blood loss by only 10 to 30 milliliters, although they prolonged the period by two days. The particular progesterone-releasing devices being tested decreased blood loss by 40 percent.[25] Although no research had confirmed that IUDs could cause anemia, developers suggested that increased menstrual bleeding might cause the health of poor women of the global South to decline since approximately half of them already had anemia or were borderline anemic. These data raised some hope in the minds of researchers that hormone-releasing IUDs might be distributed to women of the global South as protection against anemia.[26]

THE CULTURAL SIGNIFICANCE OF MENSTRUATION

In the meantime, IUD developers also began to notice that dropout rates of subjects from their studies who complained of bleeding and pain varied dramatically from place to place. A 1970 study of 14,000 users in thirty countries found that removal due to bleeding and pain was relatively rare in Europe. Yet they found significant variance in the global South. Parts of India, for example, had a much higher incidence of dropouts from studies compared to other parts of the country, whereas incidents in the Philippines were much lower.[27]

These findings prompted the Population Council to sponsor another study, this one investigating the effect of culture on IUD acceptance. Elizabeth Whelan reported that Orthodox Jewish women were five times more likely than non-Orthodox Jewish women to discontinue the IUD on account of prolonged or irregular bleeding because their religious practice mandated that women refrain from various religious, daily, and sexual activities during their period. She also identified religious texts that could have similar effects on women of other faiths.[28] Subsequently the 1979 *Population Reports,* which summarized the status of IUD research for family planning programmers and other health professionals, stated: "In countries where menstruating women are not permitted to prepare certain foods, carry on their usual household tasks, perform religious rites, or engage in sexual intercourse, any prolongation of bleeding or midcycle spotting disrupts personal and household routines. As a result, not only the IUD user but also her husband and mother-in-law may insist on removal of the device."[29] This shows that users' cultural beliefs began to be seen as part of the problem that led to the discontinuation of IUDs.

As an organization overseeing reproductive health around the globe, the World Health Organization (WHO) also recognized that menstrual disturbances, such as no bleeding, excessive bleeding, or irregular bleeding, were responsible for one-fourth to one-half of all first-year dropouts of contraceptive methods such as the IUD, progestin-only oral contraceptive, progestin-estrogen combination pill, and progesterone injection. Between 1973 and 1979, the WHO conducted an investigation of attitudes toward menstruation among 5,000 women from fourteen cultures.[30] Interviews with women affirmed that an increase in the number of bleeding days might be unacceptable in certain cultures because it interferes with day-today household or religious activities. Three-quarters of the Hindu women interviewed, for instance, said they avoided cooking for their families during menstruation; almost all respondents in Egypt, Indonesia, and Pakistan and three-quarters of Yugoslavian Muslim women believed that a woman should not visit temples when she is bleeding. The study also found that while many women felt that increased blood loss would make them physically weaker, some also believed that decreased blood loss would cause discomfort due to retention of blood within the body. Importantly, the study concluded that most women did not want any changes in their menstrual patterns.

As the WHO report was coming out, the Population Council discovered that its latest levonorgestrel-releasing device was experiencing a 20 percent discontinuation rate due to amenorrhea or other hormonal side effects.[31] At this early phase in the testing of the device, researchers had not understood that levonorgestrel stopped menstrual bleeding altogether in 20 percent of users. The initial high dropout rate therefore was later attributed to uninformed physicians who removed the device out of concern that was actually unwarranted. But this explanation provided only a small consolation since the WHO study had also found that the majority of women interviewed stated that they were "not prepared to accept" a contraceptive if it led to amenorrhea.[32] The rates of women rejecting amenorrhea varied from 53 percent of British women to 91 percent of Punjab women in Pakistan, while their reasons ranged from fear of impairing their health by disallowing what they viewed as "bad blood" to purge and reluctance to tamper with nature to the negative indications of menopause and infertility associated with having no periods.

Defying the original expectation that reduced blood loss and less cramping with progesterone-releasing devices would increase IUD acceptance in the global South, the 1982 *Population Reports* concluded that removal rates in several trials were similar to or worse for the hormone-releasing devices as compared to the copper-bearing ones.[33]

Although levonorgestrel had achieved the "bloodless, comfortable IUD" sought by USAID, the cultural significance of menstruation appeared to be working against the acceptance of an otherwise effective device. As this perception unfolded, the conceptual division between users of the global North and South widened.

CONFIGURING THE MODERN WOMAN/CONSUMER

The WHO study also offered subtle yet significant insight into who may be more inclined to accept modern contraceptive methods that alter menstrual patterns. For instance, the report noted that beliefs associated with menstruation, such as that one should not bathe or visit the temple while bleeding, were more commonly held by "older, less educated, rural women." In contrast, a woman who was "prepared to accept" amenorrhea was reportedly "younger, better educated, [and] urban."[34] Family planning in the global South has been closely linked to the idea of modernity representing enlightenment values of secularism, rationality, scientism, and optimism for the future. As Nilanjana Chatterjee and Nancy Riley point out, the modern subject has been construed as a rational, autonomous individual who can control her environment and shape her own future by embracing scientific knowledge and technological innovations.[35] As researchers took notice of the cultural significance of menstrual disturbance, however, they began to see that some women who lacked education and led a preindustrial lifestyle were not modern enough to accept scientific methods of fertility control that change bleeding patterns.

The presumed unpreparedness of women of the global South to accept the new contraceptive was compounded by the way clinical studies in the region were interpreted and represented. An Indian study comparing the copper-bearing to the levonorgestrel-releasing device found that the continuation rate of the latter was significantly lower due to amenorrhea and irregular bleeding.[36] The seven-year study initiated by the Population Council, which took place mostly in clinics located in the global South, including Brazil, Egypt, Chile, the Dominican Republic, Brazil, and Singapore, also showed a better continuation rate for the copper-bearing device.[37] The double-blind test protocols that prevented physicians from providing adequate counseling about amenorrhea may have increased the number of removals in these trials. But this background was obscured when the 1995 *Population Reports* simply noted that LNG-IUD removal rates were higher than copper-bearing IUDs in the global South due to amenorrhea.[38] The report left the impression that LNG-IUD was not well suited for women in underdeveloped areas who embody premodern ideas about menstruation.

The *Population Reports* then presented a contrasting conclusion from a European study, which had resulted in less common discontinuation for bleeding and pain with the LNG-IUD than with the copper IUD.[39] The comparable success of the LNG-IUDs in the European study conducted in Denmark, Finland, Hungary, Norway, and Sweden was attributed to having provided detailed information regarding the contraceptive method to the women who received it. Health care personnel in the European trial explained to their patients how the effect of the hormone reduces the buildup of the uterine lining that sheds during menstruation. They also informed them that amenorrhea is not a sign of pregnancy or menopause, that the ovarian function is continuing even in the absence of menstruation, and that amenorrhea does not reduce the ability to conceive after removing the device. In addition, Scandinavian women were told that the LNG-IUD had a high level of effectiveness, which motivated them to continue using the method. Some were also advised of the device's benefits, such as increased hemoglobin, better iron stores, general well-being, and relief from dysmenorrhea and prolonged bleeding. Information regarding what women should expect to experience with this device as well as its health benefits were also disseminated through mass media. Tapani Luukkainen, whose name is often associated with the invention of LNG-IUDs, explains that offering open and accurate information has contributed to the acceptance of this method of contraception.[40]

Based on the positive responses in Europe, Luukkainen announced: "When adequately advised beforehand, most women who develop amenorrhea learn to like the new freedom."[41] This seemingly nonproblematic statement fails to recognize that a medicalized explanation of the female reproductive system may have resonated with the women in the European study due to their cultural upbringing. Medical anthropologist Emily Martin has found that middle-class American women more readily identified with the scientific model of menstruation as compared to working-class women, who resisted medical explanations of their embodied experiences.[42] Martin's findings suggest that certain groups of women are more amenable to seeing their bodies in physiological terms, making them good candidates for accepting the information of the hormonal effects on their reproductive systems. Luukkainen does not address how "adequate advising" may work for women whose understanding of their bodies departs significantly from the medicalized version. His suggestion to educate women may certainly be effective for the middle class of the global North but does not necessarily take all women into consideration. In fact, as Stacy Pigg points out, knowledge of bodies is always cultural and there exists no neutral biological language that is equivalent across cultures. Insisting on Western scientific understandings of reproduction thus could constitute "epistemological colonization" or violence.[43]

WRITING OFF LESS MODERN WOMEN

After the comparative clinical trials in the global South showed a lower retention rate for hormonal devices, there has been little attempt to see if acceptance by these women could be improved if they were "adequately advised." In fact, interest in women who were not ready to accept amenorrhea faded as researchers turned their attention to women who might "learn to like" the period-less lifestyle. If there are indeed health benefits of this device, such advantages are being denied to women of the global South, who are implicitly written off as being not modern enough to appreciate the new technology.

Perhaps IUD developers have simply lost interest in women who they deem as less modern. But there is also little incentive for family planning supporters to strongly promote the distribution of this device overseas, now that the copper-bearing devices are widely accepted. This is particularly so since they are just as effective in preventing pregnancy and are much more economical. When asked whether USAID would provide Mirena to overseas family planning programs, Dr. James D. Shelton, senior medical scientist of the agency's Office of Population, gave this answer on his Q&A Web site, *Jim Shelton's Pearls:* "Cost is likely to be an insurmountable hurdle. . . . Bear in mind, the Copper-T-380A is an excellent and inexpensive IUD. So after factoring in the costs of introducing a new method, the advantages of Mirena would only justify USAID large-scale procurement in the face of a very attractive price."[44] This statement construes Mirena as being too expensive for aid agencies to supply to women in the global South because the copper T is an adequate cheaper alternative.

In order to close some of the economic gap, the Population Council and Mirena manufacturer Schering Oy established the International Contraceptive Access Foundation (ICA) in 2004. ICA offers a combination of donation and subsidized sale (for a maximum of $40 per device) to the public sector for a limited number of units. The ICA also conducts projects in twelve countries supporting Mirena use in family planning programs.[45] Nevertheless, the $40 price tag is still vastly more expensive than the $1.64 that USAID supplies the copper T for. Copper IUDs can actually be obtained as cheaply as $0.25 a unit.[46] The economic factor clearly widens the gulf between the reproductive choices of women in the global North and South.

The economic divide is present in the United States as well. Mirena costs around $500 at a doctor's office, compared to about $250 for ParaGard, in addition to the office visit charges and fees for screening tests.[47] State Medicaid programs may cover Mirena at various levels of reimbursement, and an uninsured patient whose income is below the poverty level can apply for a free device with her provider through a program funded by Bayer HealthCare Pharmaceuticals.[48] More often than not, however, women must cover all or part of the expense. Paradoxically, despite the high initial cost, IUDs, including the Mirena, are the most cost-effective form of reversible contraception.[49]

As ideas formulated regarding who would accept a device that dramatically changes menstrual patterns, who could be educated to appreciate decreased menstrual bleeding, and who could afford the high initial expenses, the original intention to promote the hormone-releasing IUD in the global South to boost contraceptive acceptance evaporated. Developers instead found new interest in applying the device's unique side effect to gynecological treatments, as we shall see next. Looking at these ironic transitions teaches us a few things: biopolitical investments in women's bodies diverge over space and time; developers transfer their interests from one type of device application to another without explicit reflections on how they perpetuate inequality; and technological practices are imagined with implicit assumptions about differences between women of the global South and North. Significantly, shifting interests kept the momentum for the exploration of hormone-releasing devices.

A CONTRACEPTIVE WITH THERAPEUTIC PROPERTIES

One such interest was the idea of turning the hormone-releasing IUD into a therapeutic device. When the original progesterone-releasing devices were found to decrease menstrual blood loss by 40 percent, researchers toyed with the idea of using hormonal IUDs to treat or prevent anemia. Applying the device to anemia was a logical extension of their initial goal to improve the method's acceptance in the global South: the device would be more attractive if it could be argued that it had additional health benefits for the population. To this end, the ICCR conducted a study in the Dominican Republic in the late 1980s and found that the LNG-IUD appears to reduce the proportion of women with clinical anemia and improve their iron level.[50] Researchers concluded that the device might become a strong health-enhancing tool since it both prevents pregnancy, which depletes women's energy, and decreases blood loss that leads to anemia. In other words, investigation into applying the device for the improvement of women's health was initiated in relationship to a disease that is more prevalent in the global South. Applications to other gynecological conditions, however, quickly took over.

In a 1995 article, Tapani Luukkainen and Juhani Toivonen reconceptualized the levonorgestrel-IUD as a contraceptive with "therapeutic properties."[51] They reported that the LNG-IUD dramatically improved the conditions of women who suffered excessive menstrual bleeding, a condition called menorrhagia, and that the device might offer an alternative for surgical treatments such as hysterectomy and endometrial ablation (destroying of the uterine lining). They introduced findings that showed the LNG-IUD reduces endometrial hyperplasia, or the excess growth of the uterine lining, which occasionally leads to uterine cancer. They announced that these "promising findings" warrant further investigations into the use of the device to treat this problem.[52] They also reported that some observations suggested that long-time use of the device reduced the incidence of uterine fibroids (benign uterine tumors that can cause painful periods, back pain, and sometimes infertility). And they added that the LNG-IUD could also be used to prevent the endometrium from cancerous growth in women who are taking estrogen to manage menopausal symptoms.

Luukkainen's enthusiasm was amplified ten years later, in 2005, at the Fifth International Symposium on the Intrauterine Devices and Systems for Women's Health sponsored by the Population Council and the United Nations Population Fund, which I attended. Nearly half of the presentations focused on the levonorgestrel intrauterine system, many of them discussing experiences or the possibilities of applying the device to treatment or prevention of gynecological conditions. Illnesses mentioned included menorrhagia, dysmenorrhea (menstruation accompanied by severe pain), endometrial hyperplasia, endometriosis (uterine-lining-like tissue growing outside the uterus, which can cause debilitating pelvic pain and can also cause internal organs to fuse together), adenomyosis (uterine lining tissue that grows inside the muscular wall of the uterus, causing pain), uterine fibroids, uterine polyps, and endometrial carcinoma (uterine cancer).[53] The possibility of seeking FDA approval to prescribe the device as the progestin component of hormone replacement therapy for menopausal women was also discussed.[54] Overall, the researchers were excited about conducting more studies and the possibility of their device's being offered as an alternative treatment to surgery or oral progestin treatments for many gynecological disorders. Incidentally, Mirena received FDA approval in early 2010 for the treatment of menorrhagia.

The growing interest in the therapeutic use of the LNG-IUD further steered its researchers away from their initial neo-Malthusian intentions to distribute the device to women in the global South. Preventing or healing disease and maintaining the health of their own patients as well as encouraging their colleagues to adopt this new technique, have instead become the new biopolitical interest for Mirena researchers.

THE BIOPOLITICAL SCRIPT OF MENSTRUAL SUPPRESSION TECHNOLOGIES

Surpassing the device's promise for the diseased patients is the appeal that device-induced menstrual pattern changes has for general consumers. Contraceptives that are approved as menstrual management methods have paved the way for Mirena to be perceived as having a similar benefit. Less apparent is the fact that the histories of these medications are intimately linked to the development of the LNG-IUD with overlapping researchers.

IS MENSTRUATION OBSOLETE?

Contraceptive developers were paying attention to altered menstrual patterns before they became an issue for IUD users. During the 1950s, Gregory Pincus, the inventor of the first oral contraceptive, noticed that his trial subjects became distressed when they experienced amenorrhea, which led him to believe that women wanted to feel that they were menstruating naturally. Then the director of biological research of G. D. Searle, the first company to market oral contraceptives, told Pincus that he "did not want to take part in the development of any compound that might interfere with the menstrual cycle."[55] In response, Pincus devised a way of mimicking nature by creating the seven-day bleeding period every twenty-one days, which is actually caused by taking sugar pills for a week instead of hormones.[56] The inventors of the oral contraceptive thus effectively configured a woman whose "normal" periods consist of a twenty-eight-day menstrual cycle twelve times a year.

Forty years later, contraceptive researchers started to reconfigure the menstruating subject. After decades of experience with contraceptive methods that inadvertently affected menstrual patterns, Elsimar Coutinho and Sheldon Segal, who were involved in the development of both the Norplant and the LNG-IUD, published *Is Menstruation Obsolete?* Their 1999 book contends that menstruation is "an unnecessary, avoidable byproduct of the human reproductive process."[57] The authors state that regular and recurrent menstruation throughout most of a woman's fertile years is a fairly recent phenomenon of the industrialized world: women used to have very few periods when they nursed babies for an extended period of time and gave birth multiple times throughout their reproductive lives. The authors argue that the common perception that menstruation is a natural event that is somehow beneficial to women has no scientific basis.

Since there were no products indicated for menstrual suppression on the market yet, Coutinho and Segal proposed that women should start using available methods to stop menstruation "with the cooperation and supervision of their physicians."[58] This could be done, for instance, by skipping the sugar pills in standard oral contraceptives. The authors predicted that suppressing menstruation "would forge a major advance in women's health, led by women" and that "today's proposal would become tomorrow's new paradigm."[59] Subscribing to the idea that biological differences hold women down and proposing to liberate them from their innate imperative, the authors quoted the most prominent birth control activist of all times, ending the book by stating, "The pioneer feminist Margaret Sanger wrote 'No woman is completely free unless she has control over her own reproductive system.' Let this new freedom begin."[60] Their prediction about the new paradigm has for the most part come true. Although pharmaceutical companies, instead of women, led the way with their new products, the idea that a woman could suppress her menstruation to free herself from an unnecessary burden has taken hold among consumers in North America and Europe.

MARKETING MENSTRUAL SUPPRESSION PRODUCTS

Laura Mamo and Jennifer Fosket illustrate how Seasonale, an oral contraceptive that produces menses-like bleeding cycles four times a year, rewrote the norms of menstruation and menstruating subjects through its product campaign. In the absence of either pathology or an at-risk state that requires medication, the Seasonale campaign constructed menstruation as an inconvenience and an obstacle that the drug could eliminate. It told women, "There is no medical reason to have [a period] when you are on the pill," suggesting that since the periods that pill users experience are in effect created by the medication, reducing the frequency of unnatural periods is perfectly reasonable.[61] Its marketing discourse also "produced associations between cleanliness and femininity, between freedom of movement and women's bodies, and between limited menstrual flow and natural embodiment," thereby reconfiguring the nonmenstruating woman as desirable and feminine.[62]

Since the launch of Seasonale by Duramed Pharmaceuticals in 2003, a number of similar products have been introduced. Seasonique from Duramed also induces menstrual-like bleeding every three months. The TV commercial for this product shows a physician, who announces, "There is no medical need to have a monthly period on the pill. Lots of women are having four periods a year." Based on what she learned from the doctor, a young woman in the ad decides to use the drug, conveying to the viewers that such a decision is a logical one. A rival product, Loestrin 24 Fe from Warner Chilcott, reduces monthly bleeding to three days or less. This product is marketed with a catchphrase, "Say so long to a period that's too long." Its advertisement features Cammie, a young, active, and attractive woman living in an artsy neighborhood in New York City. Suggestive scenes of a bouquet of red roses and of a man's arm around her waist send the message that the drug produces an appealing heterosexual female body that is available for sex for more days each month. Finally, the most recent product, Lybrel from Wyeth Pharmaceuticals (now Pfizer), eliminates bleeding entirely within about six months by continuously taking progestin-estrogen combination birth control pills. As with other lifestyle drugs, modifying the material body with menstrual suppression products produces culturally and socially meaningful positive changes in the identities and lives of their users.

MIRENA'S ADDITIONAL BENEFIT AND GOVERNMENTALITY

Mirena is not explicitly marketed as a menstrual regulation product. Yet some of its informational material, such as the pamphlet provided to prescribing physicians, highlights the side effect as an "additional benefit."[63] The 2006 educational DVD for patients also promotes this aspect with an illustrative episode of an apparently athletic career-oriented woman, who recommends Mirena to her sister because she likes not having her period. The 2008 TV commercial, which introduced the product widely to prospective consumers, merely mentions a "shorter lighter period" as a common side effect. Yet since many women are already familiar with menstrual-suppression contraceptives, they are likely to interpret reduced bleeding as a bonus feature.

Women who blog about how much they love Mirena regularly attribute their satisfaction to their nonmenstruating bodies as much as they do to not having to worry about forgetting to take the pill.[64] The precedence of menstrual-suppression medications prepared Mirena users to view their experience with the device as an enhancement of lifestyle. These commercial products have reconfigured menstruation and the menstruating subjects, successfully transforming the meaning of monthly periods from a necessary part of womanly embodiment to an event that can be manipulated to suit one's lifestyle.

A biopolitical script based on market logic and capitalist lifestyle has been co-configured into menstrual-suppressing contraceptives. As Patrick Joyce points out, the emergence of liberalism in Europe "depended on cultivating a certain sort of self, one that was reflexive and self-watching."[65]

The enlightened women who make conscious decisions about how they are going to manage their reproductive lives and maximize their bodily functions to live life smartly and productively are *ruled through freedom*. The marketing of this lifestyle drag relies on self-governing subjects whose desires are cultivated through the advertising, who exercise their right to manage their own fertility, and who choose to maintain their reproductive health. In the context of the American market, the biopolitical subjects of the long-acting menstrual-free IUD are largely invested in as a site of consumption rather than as an overtly fertile population. They are the subjects of liberal governmentality. A closer investigation of how IUD users are represented in product promotional materials, however, offers additional insight into how governance over women's bodies is delicately differentiated at intersections of race and class.

THE RACIAL ECONOMY OF IUD PROMOTION IN THE UNITED STATES

Marketing endorsements of IUDs today argue that the contraceptive method has advantages over the pill and barrier methods because it has long-term effectiveness that offers convenience and a lower rate of user failure. They also promote it as being favorable compared to surgical sterilization: the device's contraceptive effect is reversible, and it preserves future fertility. Not all women's reproductive choices, however, are represented equally in the advertisements. The device's benefits tend to be advertised through representations of women who are subtly differentiated in accordance with cultural expectations about how certain groups of women should regulate their reproductive capacities. While the construction of the North/South divide in IUD applications reflected ideas about modernity based on regionalized racialization and economics, promotional materials for the devices within the United States reveal that biopolitical interests are segmented based on race and class, mirroring American social relations.

Terri Kapsalis makes a similar observation in a three-page Norplant advertisement printed in a nurse practitioner's journal in 1992, arguing that they implicitly reinforce race-based reproductive politics.[66] Both of the two white women featured in the ad have children and appear modern, wealthy, and family oriented. The first woman chose Norplant because she is mostly certain that she completed her family but would like to leave open the option of having more children, while the second one is using the implant to time the birth of the next child she plans to have. Both are photographed with their children. The African American woman in the advertisement, in contrast, has no children. Rather, she is using Norplant so that she can finish nursing school before she has a family. Kapsalis points out that the representation of the childless African American woman reflects the idea that a black woman should establish herself economically before she has children and signals that Norplant will aid this process. She argues that these advertisement images and narratives "play into current dominant constructions of proper African American women's reproductive identity."[67] I would add that a strong expectation toward family orientedness in white women is also embedded in these advertisements.

Subtle but racially distinct similar messages are present in the marketing of IUDs. Of the two products available in the United States, the ParaGard Web site shows far more diversity than the Mirena site.[68] Women represented on the Mirena site are mostly upper-middle-class white women with their male partners and children; only one light-skinned African American woman can be found posing with her even lighter-skinned baby girl, but without a male partner, in a tastefully decorated nursery.[69] One can deduce that the primary target niche market for this product is well-to-do mothers.

In comparison, ParaGard reaches out to a broader consumer base, including women who have not had children. The product home page features five racially diverse women. With a scroll of the mouse, the viewer can read the reason each woman chose ParaGard. The Asian woman, who is "single and planning for the future," is "in a serious relationship, but not ready for a family." She represents a woman of color who is expected to establish her livelihood before she has children. The race of the woman in a business suit standing confidently in the center can be read as either a dark-haired white person or a very light-skinned Latina. She represents a career-oriented woman who wants to put off having a family. One of the African American women appeals to prospective users who are "concerned about hormonal health risks" and want "highly effective birth control" without hormones and their side effects. The other African American woman is "living the change of life" and represents older consumers. Her testimony reads: "Done with family. Done with pills, patches, and rings. Wants simple birth control to last until menopause." Whereas the Asian and Latina/white women clearly express the desire to have children in the future, the two African American women do not. The second woman explicitly states her childbearing is complete, and the first woman makes no mention of wanting a child.

African American women's desire to restrain their fertility is a culturally appropriate script that is also played out in the representation of Mirena users. The Mirena patient education DVD features women of color in only one of the four episodes: two African American women discuss Mirena as a good option for them because their chaotic lives with children make it challenging to remember to take the pill. One of them (whose feature can also be read as a non–African American woman of color) is pregnant with her second child and asks her gynecologist if Mirena is right for her; the white female doctor assures her that it is not too early to plan on getting it during her postnatal checkups. An ideal user for Mirena as represented in this episode reiterates the notion that the IUD is a suitable contraceptive for women who are unreliable pill users (who are often marked by their race, class, and young age) and for restraining the fertility of women of color.

The three educational DVD episodes involving white women include the one I have already mentioned, which features an athletic businesswoman who appreciates not having her period. The second skit shows a new mom with her husband. She wishes she did not have to fiddle with the diaphragm whenever the couple finally has a moment to themselves. Sure enough, her doctor recommends Mirena. This scenario highlights the sexual spontaneity and convenience that Mirena users in a stable relationship enjoy. The last episode presents a blond white woman with three children. She says she considered tubal ligation, but decided to get a Mirena instead because she is not completely sure if she is done having children.

There is a striking similarity between this woman and the fifth woman shown on the ParaGard Web site. She is also a blond white woman, who "loves being a mom." With a scroll of the mouse, we learn that she "adores her kids. Wonders what it would be like to have more. Wants hassle-free birth control that won't limit her options." The Mirena TV commercial also emphasizes reversibility as an advantage of this contraceptive method, concluding the clip with a picture-perfect American family with their fourth newborn child.

But with a closer and critical look, this so-called option is presented as appropriate only for middle- to upper-middle-class white family-oriented mothers. There is an enduring pattern that shows a cultural preference toward fecund women to be portrayed as white and well-to-do and toward women of color to express the need to suppress reproduction.

In an essay titled "Will the 'Real' Mother Please Stand Up?: The Logic of Eugenics and American National Family Planning," Patricia Hill Collins argues that in the United States, "where social class, race, ethnicity, gender, sexuality, and nationality comprise intersecting dimensions of oppression, not all mothers are created equal."[70] The idealized mother best suited for the tasks of reproducing both the American nation and seemingly American values is embodied by an affluent white woman bearing American citizenship who reproduces her biological children and physically participates in every facet of their lives. These kinds of mothers, whom Collins calls "real" mothers, encounter social policies, institutional arrangements, and ideological messages that encourage and support them to continue to reproduce. For instance, the availability of medical services to combat infertility simultaneously supports and obligates upper-middle-class white women to reproduce their biological offspring. Images of large, happy families with distinctly white upper-middle-class features such as the ones shown on IUD commercials are examples of the encouragement that "real" mothers receive. In contrast, mothers who are considered less fit and even unfit are discouraged from having children and do not receive similar support for parenting. The reproductive options that are prescribed to working-class black women, in particular, often derive from the racist notion of poor African American women who have too many children and become "welfare queens." Collins argues that both positive and negative eugenics, which are based on the race and class of the mothers, are still present in contemporary American society. We indeed see them manifest in contraceptive advertisements.

On the surface, ParaGard and Mirena IUDs have joined the myriad birth control options available to American consumers. Yet various aspects of the contraceptive method are matched up with culturally sanctioned body/technology relationships. Although sometimes bodies cross over the dichotomous categories, reversibility is generally stressed for what are viewed as real American mothers, and other aspects, such as the ease of use and long-term effectiveness, are promoted through the bodies of women of color. The initial emphases IUD researchers placed on controlling the birthrates of undesirable populations and disciplining women's bodies to suppress socially problematic pregnancies are still embodied by this seemingly progressive lifestyle product.

BODY/TECHNOLOGY RELATIONSHIPS IN RACIALIZED GLOBAL CONTEXTS

During its fifty years of development, the IUD discourse has generated diverse body/technology relationships while representing scientific findings in biopolitically and geopolitically meaningful ways. From being the population control tool it once was foreseen to become, the hormone-releasing device diversified into a gynecological treatment, a menstrual-suppression technique, and an alternative to tubal ligation. The diversification, however, applies for the most part only to the global North. The International Contraceptive Access Foundation, an organization that donates free LNG-IUDs to family programs overseas, states, "ICA aims to serve the needs of women and families in the developing world to achieve their desired family size and birth spacing."[71] As this statement suggests, the biopolitics of contraceptive technologies in the global South continue to focus on fertility, although the rhetoric has moved away from justifying mass insertions. The pairing of excessively fertile bodies and an effective long-acting contraceptive technology remains the dominant paradigm there.

Contested meanings of menstruation have contributed to reinforcing the divide between bodies in the global South and North by creating an additional dichotomy between "backward" and "modern" contraceptive users. Women who were deemed not ready to appreciate amenorrhea due to their cultural beliefs about menstruation were left behind in the popularization of the hormone-releasing device. Meanwhile, those regarded as accepting of the scientific explanation of why women should embrace less menstrual bleeding were thrust into a new paradigm of bodily enhancement and lifestyle medications. The cost of Mirena, too, has contributed to the separation between underprivileged women, for whom effective contraceptives are rendered adequate, and economically privileged women, for whom a favorable contraceptive should offer extra benefits.

As Mirena's common side effect acquired new meanings, body/technology relationships in the global North expanded. IUD developers interested in treating menstrual disorders and uterine ailments reconceptualized the device as a therapeutic technology and gynecological patients as treatable bodies. Much less concerned with reproduction, this body/technology coupling represents the biopolitics of health maintenance. The menses-free body/device also entered a market already sold on the idea of artificial menstrual suppression as lifestyle choice. Liberal governmentality or self-management for achieving better health, higher productivity, and a happier life connects the desiring consumer to this new contraceptive with an additional benefit.

The latest body/technology relationships in IUD promotional materials also represent contemporary eugenics ideologies promoted within the framework of individualism. The 1995 Hastings Center Report on the ethics of long-acting contraceptives signify a shift in the approach to suppressing undesirable pregnancies from targeting specific groups to holding individuals responsible. Authors of the report take great caution not to approve of broad use that may suggest racial and class discrimination. Yet at the same time they explore acceptable ways to discourage what they see as irresponsible reproduction. The overall report leaves an opening for an argument to be made for promoting long-acting contraceptive methods in limited cases that are evaluated on an individual basis. The individualist approach easily blends with a consumerist framework and naturalizes the coupling of racialized bodies, understood as potentially "unfit mothers," with long-acting and user-failure-free contraceptives. Meanwhile, white mothers' bodies are unproblematically paired with the reversible feature of the IUD, implicitly promoting positive eugenics through consumption.

By following the development of Mirena, this essay traced how diverse biopolitical subjects were constructed within the IUD discourse in accordance with cultural expectations about race and class, as well as the global political economy of women's bodies that render some as overproducing fertility machines and others as sites of consumption of medical services and devices. It also revealed how various body/technology pairings were configured, forming a network of relationships that reflect the racialized global context within which technoscientific interventions in women's bodies are imagined.

NOTES

1. For more detailed perspective on my academic and personal journey with an IUD, see Takeshita (2010).
2. Posting on an online medication discussion resource, medications.com: http://www.medications.com/effect/view/34880 (accessed November 2010).
3. See for example, http://lifeaftermirena.blogspot.com
4. See Mamo and Fosket (2009).
5. See Loe (2004) and Mamo and Fishman (2004).
6. Blum and Stracuzzi (2004).
7. Scommegna et al. (1970).
8. Ibid. (201, 202).
9. Ibid. (209).
10. See Scommegna et al. (1974). This research was also funded by the Ford Foundation. This time, they tested a T-shaped progesterone-releasing device in 249 women for twelve months. No pregnancies resulted.
11. See Huber et al. (1975) and Piotrow, Rinehart, and Schmidt (1979).
12. See Segal (2003).
13. Population Council (1970).
14. Norplant consists of six levonorgestrel-containing matchstick-size rods that are implanted beneath the skin of a woman's forearm to prevent pregnancy for five years.
15. Prager and Darney (2007).
16. Moskowitz, Jennings, and Callahan (1995, S1).
17. See Watkins (2010a, 2010b).
18. Smith (2005b).
19. Moskowitz, Jennings, and Callahan (1995, S2).
20. The documentary film Skin Deep by Frances Reid records testimonies of women who suffered side effects from Norplant. See Reid (1995).
21. This report, Moskowitz, Jennings, and Callahan (1995), from the Hastings Center has been published as an edited volume: Moskowitz and Jennings (1996).
22. Huber et al. (1975, B-38).
23. "Uterine tranquilizer" appears in ibid.
24. See Tietze and Lewitt (1968).
25. See Liskin (1982).
26. See Treiman and Liskin (1988).
27. See Bernard (1970).
28. Whelan (1975).
29. Piotrow, Rinehart, and Schmidt (1979, B-66).
30. The WHO (1981) study was conducted between 1973 and 1979 and involved 5,322 parous women from fourteen cultural groups in Egypt, India (Hindu high caste, Hindu low caste), Indonesia (Javanese, Sudanese), Jamaica, Korea, Mexico, Pakistan (Punjab, Sind), the Philippines, United Kingdom, and Yugoslavia (Muslim, non-Muslim).
31. See Liskin (1982).
32. WHO (1981, 12).
33. See Liskin (1982).
34. WHO (1981, 13).
35. Chatterjee and Riley (2001).
36. The continuation rates for the levonorgestrel IUD were 74.5, 58.7, and 38.8 percent at one, two, and three years respectively. The continuation of copper devices ranged from 82.4 to 84.4 percent at year 1, 66.6 to 69.9 percent at year 2, and 45.4 to 50.4 percent at year 3. This was a double-blind trial, which disallowed physicians to provide consultation to women who received the LNG-IUD about possible amenorrhea. Thus the high discontinuation rate may have partly been corrected with counseling. See Indian Council of Medical Research (1989).
37. See Sivin et al. (1991).
38. Treiman et al. (1995).
39. Ibid. For the original report of the European study, see Andersson, Odlind, Goran Ryobo (1994).
40. Luukkainen (1994).
41. Ibid. (39).
42. Martin (2001).
43. See Pigg (2001). See also Adams and Pigg (2005).
44. Jim Shelton, "IUD Mirena," Dr. Jim Shelton's Pearls. January 15, 2001. http://info.k4health.org/pearls/2001/01-15.shtml (accessed November 2010) Shelton explains: "In the private sector at least, the price is likely to be in the hundreds of dollars. Over the years AID staff have had discussions with Schering (and with its predecessor Leiras) about an acceptable public sector price. Although we have never been able to reach accord, we will keep trying." USAID was not supplying Mirena at the time of writing this book.
45. Under their agreement, product donations to international development agencies and public health organizations can be made up to 1 percent of non-U.S. market unit sales (about 53,000 IUDs by 2007). In addition, the company will sell up to 3 percent of non-U.S. market unit sales for under $40 to qualified public sector organizations. ICA has projects in Brazil, Curaçao, Dominican Republic, Ecuador, El Salvador, Ghana, Kenya, Indonesia, Nigeria, Paraguay, Saint Lucia, and South Africa. http://www.ica-foundation.org/ (accessed November 2010).
46. Rademacher et al. (2009). Available at http://www.k4health.org/toolkits/iud/essential-knowledge-about-lng-ius (accessed November 2010).
47. These cost figures are based on my own experience between 2002 and 2005. Prices vary

depending on the provider, and distributors' business decisions may affect future prices.
48. ARCH Foundation, http://www.archfoundation.com/ (accessed November 2010).
49. Rademacher et al. (2009). See also Trussell, Lalla, and Doan (2008).
50. Faundesa et al. (1988).
51. Luukkainen and Toivonen (1995).
52. Ibid. (274).
53. See Fraser (2007).
54. See Rarick (2007).
55. Oudshoorn (1994, 121).
56. Ibid.
57. Coutinho and Segal (1999, 163).
58. Ibid.
59. Ibid. (164).
60. Ibid.
61. Mamo and Fosket (2009, 933).
62. Ibid. (931).
63. Mirena promotional material from October 2006 for prescribing physicians.
64. See note 2.
65. Joyce (2003, 4).
66. Kapsalis (1997).
67. Ibid. (53).
68. ParaGard product Web site: http://www.paragard.com/home.php (accessed November 2010).
69. Mirena product Web site: http://www.mirena-us.com/index.jsp (accessed November 2010).
70. Collins (1999, 266).
71. www.ica-foundation.org (accessed November 2010).

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SECTION III

Technologies of Sex, Gender, and Difference

CHAPTER 16

Science, Power, Gender: How DNA Became the Book of Life

Ruth Hubbard

Natural science, which is what we usually mean by *science,* involves interacting with nature in ways that produce certain kinds of interpretations of how nature works. There are different styles of doing science, depending on what aspects of nature scientists are exploring, but all of them are constrained by rules of what constitutes evidence and what conclusions are considered permissible. The different ways in which scientists pursue their work, however, do not easily fit into male/female categories.

The fact that, in the United States, many more physicists are men than women has to do with the social and economic structure of domestic life, with processes of education and professionalization, and with the social history of the disciplines, not with the intrinsic nature of physicists' knowledge base or the nature of women and men. We live in a gendered society, and it should not surprise us if women and men tend to develop different tastes in the kinds of knowledge they seek and the ways they seek it, but this fact cannot be used to predict the practices of individual scientists. Besides, science imposes a hegemony within which all its practitioners must operate if they want what they do to be acknowledged as science.

In this essay, I want to describe the contributions two outstanding women scientists have made, in the course of the twentieth century, to our under- standing of how genes function and to raise the question of what ways gender can be said to have entered their scientific accomplishments and careers. But, first, I need to review briefly how, during this period, genes and DNA have come to be the iconic objects they currently are.

I

Genetics, of course, starts with the Czech monk Gregor Mendel. Using pea plants as his experimental objects, Mendel examined the transmission of flower color and of the shape and texture of the seeds to successive generations. He deliberately chose discrete traits, such as red or white petals, or smooth or wrinkled seeds, rather than traits that vary continuously, such as weight or size. He also only kept track of the mathematical regularity with which these traits are transmitted and did not speculate about what processes inside the plants are involved in transmitting the traits. He simply assumed that "factors" inside the plant mediate their transmission.

The publication of Mendel's paper, in 1865, provoked little notice. But by 1900, when the paper was "rediscovered," it aroused immediate interest. The reason is that, in the intervening years, scientists had learned a great deal about the internal structure of cells and about what happens when a cell divides and gives rise to two daughter cells. Stainable bodies, called chromosomes, had been observed in the cell's nucleus, and scientists had noted that different cells of the same organism all contain the same number of chromosomes. Scientists also noted that, when cells divide, their nuclear chromosomes split in two, which is how each daughter cell ends up with the same number of chromosomes as were present in the parent cell. On the basis of such observations, by 1900 biologists accepted that chromosomes have something to do with the way traits are trans-mitted from parents to offspring, and Mendel's hypothetical "factors" came to be conceptually associated with the chromosomes.

The Danish botanist Wilhelm Johannsen, in 1905, invented the word *genetics* to signify biological inheritance, and, in 1909, he coined the word *gene* to lend more concrete reality to Mendel's "factors." At a time when invisible atoms and quanta were being accepted into the world of chemistry and physics, biologists had little problem accepting that heredity is mediated by invisible material particles, carried on the chromosomes. And soon, as biological chemists came to identify all sorts of molecules that function in cells, one of the questions they tried to answer was what kinds of molecules the chromosomes and genes are made of and how they function.

Once chemical analyses had shown that chromosomes contain two types of very large molecules, proteins and DNA, some scientists suggested that DNA provides the chromosomes with a structural framework to which proteins attach themselves to form the genes. What gave this model plausibility was that DNA, though very large, is a relatively simple molecule, containing large numbers of just one kind of sugar and phosphate and four different kinds of the "bases," whose designations—A, G, T, and C—have become part of our ordinary vocabulary (as has the acronym DNA). It seemed hard to imagine how combinations of only these six subunits could specify all the different characteristics organisms inherit from their parents. Protein molecules, by contrast, are composed of some twenty different subunits and come in many different shapes and sizes. It therefore was logical to assume that genes were made of proteins.

By the early 1950s, however, experiments with bacteria and viruses showed quite clearly that heritable characteristics are transmitted by DNA, not by proteins. Thus DNA was generally accepted as the substance that mediates inheritance—in a word, the gene.

II

This brings us to April 1953, when three papers appeared side by side in one issue of the British science weekly *Nature*. The first, from Cambridge University, was coauthored by James D. Watson and Francis Crick; the other two, from King's College, London, were authored by, respectively, Rosalind Franklin and Maurice Wilkins with their coworkers. The Watson and Crick paper announced the now-familiar double-helical structure of DNA. The other two offered evidence in support of this structure. James Watson has described how he and Crick arrived at the DNA structure in his best-selling memoir, *The Double Helix*, published fifteen years later, in 1968.

What immediately got scientists excited about the Watson-Crick model was that it can be made to explain how DNA—"the gene"—gets copied when cells replicate. The point is this: Let us picture the double helix as two railings of a spiral staircase, each of which is composed of a long, invariant sequence of sugar-phosphate-sugar-phosphate-sugar-phosphate units. The two railings are connected by a regularly spaced series of rungs, which make them run parallel to each other. Each rung is composed of a pair of bases, and the geometry of the double helix is such that, for two bases to form a rung, an A on one railing must meet a T on the other and a G on one railing must meet a C on the other.

This geometrical requirement means that, when cells divide and their chromosomes and genes get copied, the two strands of the double helix need merely unravel bit by bit. The sequence of bases on one strand then specifies the base sequence for the synthesis of its partner. Thus, DNA ("the gene") gets copied by virtue of the requirement that an A on one strand of the double helix meet a T on the other and a G on one strand meet a C on the other, an incredibly simple and exciting outcome.

Yet this very simplicity conceals a conceptual trap, because it led scientists to describe DNA as a "self-replicating" molecule. And this has endowed the gene with the supposed power of not just participating in the metabolic and synthetic activities of cells and organisms but of masterminding and directing them. But, of course, DNA does nothing of the sort. Without the metabolic activities of cells, DNA is neither copied nor does it participate in specifying traits. Indeed, left to itself, DNA is one of the most inert and stable molecules in biology, which is why it can be isolated, still intact, from ancient fossils.

Only by ignoring the participation of the rest of the cell and organism have molecular geneticists enshrined the magic of DNA—the autonomous, all-powerful gene that does not just specify traits but produces and controls them. The fact that biologists, who are not usually known for their religious commitments, have selected "the Holy Grail" and "the book of life" as their metaphors for DNA—not to speak of President Clinton's referring to DNA as "the language in which God created life"—underlines the ideological content of molecular genetics.[1]

III

What relevance does all this have to gender? To answer this question, I want to look at the contributions two outstanding women scientists have made to our understanding of genetics and DNA. I refer to Barbara McClintock and Rosalind Franklin. I have written about Franklin's contributions before (Hubbard 1990, chap. 5), but as DNA has come to occupy not only a central role in biology but a larger-than-life role in the culture, certain elements of both her story and McClintock's story have taken on new significance.

Born in 1902 and dying in 1992, Barbara McClintock's life spanned the twentieth century. She earned a Ph.D. in botany from Cornell in the early 1920s and stayed on at Cornell's College of Agriculture on fellow- ships for several years, working on the structure of the cells and chromosomes of corn (maize) and on its genetics. At Cornell, McClintock had access to a good-sized plot in which to breed corn. She needed that because she felt she had to get to know the individual, living plants if she was to make sense of what she observed when she later studied the detailed structure of their chromosomes under the microscope.[2] When it became clear that she was not going to be offered a position on the Cornell faculty, McClintock began to look around and eventually ended up accepting an assistant professorship at the University of Missouri. There she spent a few scientifically productive, but otherwise not very satisfying, years. The facilities were not all that good, so she needed to maintain her plantings at Cornell and shuttle back and forth. She also did not interact too well with some of her colleagues, nor did she particularly enjoy teaching. When she was passed over for promotion, she felt it was time to move on. With strong support from older, established (male) colleagues, McClintock was invited to spend a year at the laboratory of the Carnegie Institution at Cold Spring Harbor, Long Island, and it became her permanent home. McClintock's lack of academic success did not stand in the way of her recognition within the profession. She was elected vice president of the Genetics Society of America in 1939 and its president in 1945. More important, she was elected to the National Academy of Sciences in 1944—only the third woman member since its founding by President Lincoln. And she won a Nobel Prize in 1983—only the second woman scientist to win an unshared Nobel, the other being Marie Curie.

From the start, McClintock made pathbreaking contributions. But since she was committed to looking at genes in the context of the whole organism, which was not the usual perspective in her field, many of her fellow geneticists simply did not understand her experiments or the way she interpreted them. When she concluded that genes can change their positions on the chromosomes, along with their functions, in response to changes within the plant and around it, this was so contrary to what geneticists believed possible at midcentury that many of them simply wrote her off. Not until the 1970s and 1980s, when comparable observations were made with bacteria, was what McClintock had been saying accepted into the canon of the field.

So what does any of this have to do with gender? Certainly, McClintock's failure to be promoted within academia had a lot to do with it, though it must also be said that she was not an easy colleague; but neither are many male academics. That colleagues chose to ignore her rather than make the effort to understand what she was saying suggests that they may not have taken her as seriously as they would have taken a male colleague of comparable experience and stature. The degree to which McClintock was something of an outsider and a loner in her scientific life (though she always had close friends) probably also had something to do with gender. But the content of her science?

Some people have suggested that McClintock relied more on intuition than do most male scientists. Probably so, but so do some men. In a recent biography of Henry Wallace, Franklin Roosevelt's two-term secretary of agriculture and one-term vice president, who was a world-famous plant breeder (and founder of Pioneer-Hi-Bred, the foremost supplier of hybrid corn), I found the following story. Late in Wallace's life, a group of New York writers and artists asked him to what he attributed his success as a plant breeder. Wallace responded, "Sympathy with the plant" (Culver and Hyde 2000, 518), quite like McClintock's "feeling for the organism," her phrase that Evelyn Fox Keller uses as the title for her biography.

IV

Rosalind Franklin's is a much sadder story. Franklin was born in 1920 into an established Anglo-Jewish family in London. She graduated from Cambridge University during World War II with a degree in physical chemistry and went to work doing war-related research on different configurations of carbon in coal. At the end of the war, she moved to Paris and took a position in a French government laboratory, using X-ray diffraction techniques to analyze the structure of different types of coal. After four happy years there, she reluctantly decided to return to England and, because she wanted to learn about molecules of biological interest, accepted a fellowship in the biophysics unit at King's College, London, directed by Professor John Randall.

The unit was working on the structure of DNA, and Randall asked Franklin to build a high-resolution camera with which to make more detailed measurements of the X-ray diffraction patterns of DNA than had previously been possible.[3]

King's was a much less collegial and more hierarchical place than the laboratory in which Franklin had been working in Paris, with gender- segregated "combination rooms" where the staff took their tea and morning coffee. Also, intentionally or not, Randall put Franklin into a highly ambiguous situation by leading Maurice Wilkins, the unit's assistant di-rector, to believe that Franklin and he would be working on DNA together, while telling Franklin she would be doing the X-ray diffraction studies on her own.[4] When personality conflicts began to develop between Franklin and Wilkins, she decided they would not be able to work together and set about to build a powerful X-ray camera with which she and Wilkins's former graduate student R. G. Gosling began to make a series of groundbreaking observations on DNA fibers. And before long, she obtained the sharpest X-ray diffraction image of DNA in existence that clearly showed that DNA can form a helix.

Shortly after Franklin joined the group at King's, James Watson came to Cambridge University planning to work with Francis Crick on the structure of DNA, which the two of them considered to be "the secret of life." As Watson recounts in *The Double Helix*, his first encounter with Franklin was a disaster. Soon after coming to Cambridge, Watson went to King's to attend a seminar by Franklin, but he was too busy critiquing her clothes and hairstyle to listen properly. Having misunderstood her presentation, he told what he remembered of it to Crick, and they promptly decided to use his recollection to build a model of DNA. They then invited the King's group to come and look at their model. Franklin immediately realized that it was completely inconsistent with the data she had presented at the seminar Watson had attended and decided he was not to be taken seriously. In consequence of this fiasco, their superiors at Cambridge told Watson and Crick to keep their hands off DNA and leave it to the group at King's. (Watson tells all this in the *The Double Helix*.) During the next months, unbeknownst to Franklin, two crucial things happened. One was that Wilkins showed Watson Franklin's best X-ray diffraction image, which clearly indicated that DNA forms a helix. The other was that Max Perutz, a senior researcher at Cambridge, received a research report the King's group had submitted to their funders. Knowing of Watson's and Crick's interest in DNA, he showed them the report, which included the conclusions Franklin had drawn on the basis of her X-ray image, conclusions that specified all the critical dimensions of the DNA helix.

At just about this time, Watson and Crick found out that the famous U.S. chemist Linus Pauling was about to propose a transparently incorrect structure for DNA. With that, they decided they no longer needed to consider DNA the property of King's. Armed with Franklin's calculations against which to check possible models, they went into a frenzy of model building and, within about six weeks, came up with the now-famous double helix.

The first time the group at King's realized that Watson and Crick had gone back to working on DNA was when Wilkins received in the mail a copy of the note Watson and Crick were submitting to *Nature*. He promptly decided to write an accompanying note with his coworkers Stokes and Wilson, and so did Franklin with her coworker Gosling. Franklin framed her note as though her data confirmed the Watson-Crick structure, since she had no idea that those data had been in their hands while they puzzled out the structure. And she never realized it because five years later, in 1958, at thirty-seven years old, she died of cancer. She was dead when Watson, Crick, and Wilkins shared the Nobel Prize in 1962 and, of course, when Watson published *The Double Helix* in 1968.

In fact, Watson could never have published that book had Franklin been alive. In addition to the personal jabs and the book's crude sexism, until Watson wrote *The Double Helix* only he and Crick knew that they were in possession of Franklin's calculations while they constructed their model. Clearly, except for Franklin's closest friends, the book's readers continued to overlook that fact. But certainly Franklin would have noticed!

As it was, in 1953, when the three *Nature* papers appeared in print, Franklin was in the process of moving from King's to the much more collegial laboratory of J. D. Bernal at Birkbeck College, which is where she spent her few remaining years doing outstanding work on the structure of viruses.

So, again, how does gender come into this story? Gender no doubt had something to do with Franklin's unsatisfactory experience at King's. It probably also had something to do with the way Watson and Crick dealt with her data (though the misappropriation of data need not involve gender). It perhaps also was at least partly responsible for Franklin's lowly academic status, though she was still young and, at the time of her death, was in the midst of negotiating a move to a research position with secure, long-term funding at Cambridge University for herself and her principal collaborators at Birkbeck.[5]

Perhaps the most interesting aspect in terms of gender politics, however, is the way Watson used sexist stereotypes to obscure what should have become a scientific scandal. As Franklin's friend Anne Sayre recognized the moment she began to read *The Double Helix,* the creation of "Rosy," the humorless, dowdy, castrating female who, rather than help her dedicated male "superior" Wilkins, as she was meant to do, insists on imposing her own ideas, has the function of getting the reader not to notice that Watson and Crick had access to Franklin's unpublished data while they made their biology-shaking discovery.

If not for the fact that Franklin had long since died, Watson could not have written that story the way he did—or, more likely, at all. That he wrote it and that his breezy description of the way he and Crick came to the double helix succeeded in burying the unsavory details can surely be attributed to sexual politics. But, as I have argued before, gender was not an issue in Franklin's science any more than it was in McClintock's.

That McClintock's science was highly individual is clear. Indeed, some have argued that her scientific iconoclasm was not unrelated to the apparent comfort she took in her outsider status, which must have at least partly had to do with being a nontraditional woman. Also, Franklin's work was probably influenced by her exclusion from the King's/Cambridge fraternity, though she, too, did not let that stop her. Other women, in addition to McClintock and Franklin, have been at the forefront of genetics and molecular biology. The fact that news stories about this highly publicized field usually feature male scientists (and especially Watson) simply illustrates the gender politics of our culture.

All this is not to say that being a woman or a man is irrelevant to the way one does science. No doubt, our experiences affect what aspects of the world interest us and how we come to think about them, but ovaries or testes do not directly affect what science we do and how we do it.

NOTES

This essay is based on a talk, given in February 2001, as part of a series of lectures organized by the Radcliffe Institute for Advanced Study on "Feminism and Science in Civil Society."

1. "Reading the Book of Life: White House Remarks on Decoding of the Genome," *New York Times* (June 27, 2000), 8.
2. My information about Barbara McClintock comes largely from Evelyn Fox Keller's McClintock biography (Keller 1983), from McClintock's Nobel Lecture, from conversations with some of her friends and colleagues, and from a conversation I had with her in the early 1980s.
3. I draw my information about Franklin from Brenda Maddox's recent biography *Rosalind Franklin: The Dark Lady of DNA* (2002); from Anne Sayre's *Rosalind Franklin and DNA* (1975), which Sayre wrote as a much-needed corrective to James D. Watson's *The Double Helix* (1968); from Watson's book itself; and from the historian of science Robert Olby's *The Path to the Double Helix* (1974). I have also consulted some of Franklin's own publications and articles colleagues and friends have written about her and have spoken with some of her friends, including Sayre.
4. Maddox 2002, 132–33.
5. Maddox 2002, 304–5.

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CHAPTER 17

The Bare Bones of Sex: Part 1—Sex and Gender

Anne Fausto-Sterling

Here are some curious fads about bones. They can tell us about the kinds of physical labor an individual has performed over a lifetime and about sustained physical trauma. They get thinner or thicker (on average in a population) in different historical periods and in response to different colonial regimes (Molleson 1994; Larsen 1998). They can indicate class, race, and sex (or is it gender-wait and see). We can measure their mineral density and whether on average someone is likely to fracture a limb but not whether a particular individual with a particular density will do so. A bone may break more easily even when its mineral density remains constant (Peacock et al. 2002).[1]

Culture shapes bones. For example, urban ultraorthodox Jewish adolescents have lowered physical activity, less exposure to sunlight, and drink less milk than their more secular counterparts. They also have greatly decreased mineral density in the vertebrae of their lower backs, that is, the lumbar vertebrae (Taha et al. 2001). Chinese women who work daily in the fields have increased bone mineral content and density. The degree of increase correlates with the amount of time spent in physical activity (Hu et al. 1994); weightlessness in space flight leads to bone loss (Skerry 2000); gymnastics training in young women ages seventeen to twenty-seven correlates with increased bone density despite bone resorption caused by total lack of menstruation (Robinson et al. 1995). Consider also some recent demographic trends: in Europe during the past thirty years, the number of vertebral fractures has increased three- to fourfold for women and more than fourfold for men (Mosekilde 2000); in some groups the relative proportions of different parts of the skeleton have changed in recent generations.[2] (See also table 17.1.)

What are we to make of reports that African Americans have greater peak bone densities than Caucasian Americans (Aloia et al. 1996; Gilsanz et al. 1998),[3] although this difference may not hold when one compares Africans to British Caucasians (Dibba et al. 1999), or that white women and white men break their hips more often than black women and black men (Kellie and Brody 1990)?[4] How do we interpret reports that Caucasian men have a lifetime fracture risk of 13–25 percent compared with Caucasian women's lifetime risk of 50 percent even though once peak bone mass is attained men and women lose bone at the same rate (Seeman 1997, 1998; NIH Consensus Statement Online 2000)?

Such curious facts raise perplexing questions. Why have bones become more breakable in certain populations? What does it mean to say that a lifestyle behavior such as

Table 17.1 Culture Changes Bones

Observation	*Reference*
Vertebral BMD (gm/cm^2) increased in young women during an eight-month program of running or weight-training compared with untrained controls.	Snow-Harter et al. 1992
Two years of aerobics and weight training enhances BMD in young women; gymnastics training im proves mechanical competence of skeleton in boys.	Friedlander et al. 1995; Daly et al. 1999
Intensive tennis playing increases bone mineral content, BMAD, and thickness of the humerus of the racket arm; the effect is especially noticeable in players who began at ages 9-10, and the effect is there for both males and females. Later-in-life start-up (29 years) resulted in more marginal effects.	Jones et al. 1977; Haapasalo et al. 1996
Cross-country skiers who train year-round have site-specific increases in BMD (study on females age -16).	Pettersson et al. 2000
In late-adolescent women, weight-bearing activities are important for determining bone density; high-impact activities modifY bone width due to increased muscle strength and lean body mass; lean mass, fat mass, weight, BMI, years of menstruation, and type of physical activity explained 81.6 percent of bone variation.	Soderman et al. 2000
In Japanese women with a genetic variant that impairs vitamin D receptor, exercise, vitamin D, and calcium intake can increase BMD.	Fujita et al. 1999
Long-term exercise improves balance in older osteoarthritic adults (fewer falls).	Messier et al. 2000
In a longitudinal study of youth ages 13-27, maintain ing at least an average weight was the best predictor of high BMD in females.	Welton et al. 1994
Premenopausal, but not postmenopausal, women respond to a regime of vertical jumping exercises with increased BMD in their femurs.	Bassey and Ramsdale 1994; Bassey et al. 1998
Physical activity and muscle strength independently predict BMD in total body and in the proximal fe mur in young men.	Nordstrom, Nordstrom, and Lorentzan 1997
Amateur sports at ages 11-30 improves bone density in a site- or stress-specific fashion (study done on young men).	Nordstrom et al. 1996; Morel et al. 2001
Prepubertal Asian Canadian boys have lowered femoral neck BMC and BMD, ingest 41 percent less cal cium, and are 15 percent less active than Caucasian Canadian boys.	McKay et al. 2000
Over three years, men and women over age 65 receiving calcium and vitamin D supplements show less bone loss in the femur and spine and a lower inci- dence of nonvertebral fractures.	Dawson-Hughes et al. 1997
Ninety percent of adolescent girls and 50 percent of adolescent boys consume less than optimal amounts of dietary calcium.	Bachrach 2001
Fifty percent of 12- to 21-year-olds exercise vigorously and regularly; 25 percent report no vigorous physical activity.	Bachrach 2001
Alcohol consumption correlates with higher BMD, smoking with lower BMD.	Siris et al. 2001

(Continued)

Table 17.1 *(Continued)*

Observation	*Reference*
Anorexia nervosa injures bone development and maintenance.	Munoz and Argente 2002
In the twentieth century, American youth of African, European, and Japanese ancestry increased in height due to changes in sitting height and increase in lower limb length.	Meredith 1978

Note: BMD = bone mineral density, BMAD = bone mineral apparent density (the measure is independent of size), BMI = body mass index, and BMC = bone mineral content.

exercise, diet, drinking, or smoking is a risk factor for osteoporosis? Why do we screen large numbers of women for bone density even though this information does not tell us whether an individual woman will break a bone?[5] Why was a major public policy statement on women's health unable to offer a coherent account of sex (or is it gender?) differences in bone health over the life cycle (Wizemann and Pardue 2001)? Why, if bone fragility is so often considered to be a sex-related trait, do so few studies examine the relationships among childbirth, lactation, and bone development (Sowers 1996; Glock, Shanahan, and McGowan 2000)?

Such curious facts and perplexing questions challenge both feminist and biomedical theory. If "facts" about biology and "facts" about culture are all in a muddle, perhaps the nature/nurture dualism, a mainstay of feminist theory, is not working as it should. Perhaps, too, parsing medical problems into biological (or genetic or hormonal) components in op position to cultural or lifestyle factors has outlived its usefulness for bio medical theory. I propose that already well-developed dynamic systems theories can provide a better understanding of how social categories act on bone production. Such a framework, especially if it borrows from a second analytic trend called "life course analysis of chronic disease epidemiology" (Kuh and Ben-Shlomo 1997; Ben-Shlomo and Kuh 2002; Kuh and Hardy 2002), can improve our approaches to public health policy, prediction of individual health conditions, and the treatment of individuals with unhealthy bones.[6] To see why we should follow new roads, I consider gender, examining where we-feminist theorists and medical scientists have recently been. In the second part of this study (Fausto-Sterling in preparation) I will engage with current discussions of biology, race, and medicine to explore claims about racial difference in bone structure and function.

SEX AND GENDER (AGAIN)

For centuries, scholars, physicians, and laypeople in the United States and Western Europe used biological models to explain the different social, legal, and political statuses of men and women and people of different hues.[7] When the feminist second wave burst onto the political arena in the early 1970s, we made the theoretical claim that sex differs from gender and that social institutions produce observed social differences between men and women (Rubin 1975). Feminists assigned biological (especially reproductive) differences to the word *sex* and gave to *gender* all other differences.

"Sex," however, has become the Achilles' heel of 1970s feminism. We relegated it to the domain of biology and medicine, and biologists and medical scientists have spent the past thirty years expanding it into arenas we firmly believed to belong to our ally gender. Hormones, we learn (once more), cause naturally more assertive men to reach the top in the workplace (Dabbs and Dabbs 2001). Rape is a behavior that can be changed only with the greatest difficulty because it is wired somehow into men's brains (Thornhill and Palmer 2001). The relative size of eggs and sperm dictate that men are naturally polygamous and women naturally monogamous. And more. (See Zuk 2002; Travis 2003 for a critique of these claims.) Feminist scholars have two choices in response to this spreading oil spill of sex. Either we can contest each claim, one at a time, doing what Susan Oyama calls "hauling the theoretical body back and forth across the sex/gender border" (2000a, 190), or, as I choose to do here, we can reconsider the 1970s theoretical account of sex and gender.

In thinking about both gender and race, feminists must accept the body as simultaneously composed of genes, hormones, cells, and organs all of which influence health and behavior-and of culture and history (Verbrugge 1997). As a biologist, I focus on what it might mean to claim that our bodies physically imbibe culture. How does experience shape the very bones that support us?[8] Can we find a way to talk about the body without ceding it to those who would fix it as a naturally determined object existing outside of politics, culture, and social change? This is a project already well under way, not only in feminist theoretical circles but in epidemiology, medical sociology, and anthropology as well.

EMBODIMENT MERGES BIOLOGY AND CULTURE

During the 1990s, feminist reconsideration of the sex/gender problem moved into full swing.[9] Early in the decade Judith Butler argued compellingly for the importance of reclaiming the term *sex* for feminist inquiry but did not delve into the nuts and bolts of how sex and gender materialize in the body. Philosopher Elizabeth Grosz (1994) claimed that sex is neither fixed nor given. In drawing on philosophers such as Maurice Merleau-Ponty (1962) and Alfred North Whitehead ([1929] 1978), Grosz differentiates herself from Butler, holding that materiality is "primordial, not merely the effect of power" (Alcoff 2000, 858). Primordial materiality, however, does not mean that purely biological accounts of human development-no matter how intricate their stories of cellular function-can explain the emergence of lived and differently gendered realities.[10]

Psychologist Elizabeth Wilson offers one of the most interesting and far-reaching critiques of feminist attempts to reclaim the body (Martin 1997; Wilson 1998, 1999). Reaching back to Sigmund Freud's work on hysteria, Wilson emerges with a new purchase on biology itself. Re iterating the varied symptoms produced by psychic trauma (blindness, localized pain, loss of smell, paralysis), she focuses on the "bio-logic" of these physical manifestations (1999). "The neurology, physiology, or biochemistry of hysterical symptomology," she writes, "can be disregarded only in a theoretical milieu that takes certain modes of materiality to be inert" (1999, 10). She suggests that just as "culture," "signification," or "sociality" contribute to the production of complex bodily responses, "biology itself" ought to be investigated as a "site of . . . complex ontological accomplishment" (10). Such investigation, Wilson argues, opens the door for a fundamental reexamination of biomedical analyses of sex differences in physiology and disease patterns. The idea of embodiment as a dynamic system of biocultural formation reaches beyond discussions of gender (e.g., Csordas 1990; Ingold 1998; Williams and Bendelow 1998)[11]

Efforts to reincorporate the body into social theory also come from the field of disability studies. Here too an emphasis on the social construction of disability has been enormously productive. Yet several authors have broached the limitations of an exclusively constructivist approach. At least two different types of critique parallel and foreshadow possible feminist approaches to a reconsideration of the body. The first demands that we recognize the material constraints on the disabled body in its variable forms and that we integrate that recognition into theory (Williams and Busby 2000). The second, more radical move is to suggest that "the disabled body changes the process of representation itself' (Siebers 2001, 738). This latter approach offers a rich resource for feminist theories of representation and another possible entry point into the analysis of materiality in actual, lived-in bodies (see also Schriempf 2001).

SEX AND GENDER IN THE WORLD OF BIOLOGY AND MEDICINE

In contrast to these new feminist explorations of the body, in the field of medicine a more limited view of sex differences prevails. Consider a recent report on sex differences issued by the National Institute of Medicine and, more broadly, the professional movement called "gender-based medicine" promoted by the Society for Women's Health Research (SWHR). The SWHR describes itself as "the nation's only not-for-profit organization whose sole mission is to improve the health of women through research . . . The Society . . . encourages the study of sex differences that may affect the prevention, diagnosis and treatment of disease and promotes the inclusion of women in medical research studies" (Schachter 2001, 29).[12] The society lobbies Congress, sponsors research conferences, and publishes a peer-reviewed academic journal, the *Journal of Women's Health and Gender-Based Medicine.*

A traditional biomedical model of health and disease provides the intellectual framework for the research conferences (Krieger and Zierler 1995). Although much of the research publicized through such conferences seems strictly to deal with *sex* in the 1970s feminist meaning of the word, sex sometimes strays into arenas that traditional feminists claim for gender. Consider a presentation that was said to provide evidence that prenatal testosterone exposure affects which toys little girls and boys prefer to play with (Berenbaum 2001). Working within a 1970s definition of the sex/gender dualism, the author of this study logically extends the term *sex* into the realm of human behavior.

For those familiar with contemporary feminist theory, it might seem that the large number of biological psychologists who follow similar re search programs and the biomedical researchers interested in tracking down all of the medically interesting differences between men and women live in a time warp. But members of the feminist medical establishment, that is, those researchers and physicians for whom the activities and programs of the SWHR make eminent sense, see themselves perched on the forward edge of a nascent movement to bring gender equity to the health care system. These feminists work outside of an intellectual milieu that would permit the more revolutionary task proposed by Grosz and Wilson, among others, that of contesting not only "the domination of the body by biological terms but also [contesting] the terms of biology itself" (Grosz 1994, 20).

Within medicine there is a lot of confusion about the terms *sex* and *gender.* Many medical texts use the terms interchangeably, while some scientists apply the term *gender* to the study of nonhuman animals, a problem also debated in the primary biological literature (Pearson 1996; Thomas et al. 2000). Lack of consistent usage promotes confusion among scientists, policy makers, and the general public, in effect foreclosing any space for the analysis of social causes of differences in health outcomes between men and women (Krieger 2003).

Helen Keane and Marsha Rosengarten (2002) have explored the body as a dynamic process out of which gender emerges. In a first example they examine the significance of anabolic steroid use on the alteration of sexed bodies, concluding that "the hormonal body is always in process rather than fixed" (269); they further explore the notion of sex/gender fixity through a discussion of organ transplantation between XX and XY individuals. Finally, they examine "the biological *as* a field of transformations, as active, 'literate matter' as well as an effect *of* mediation and intervention" (275). I have chosen bone development-an area often accepted as an irrefutable site of sex difference-to examine Keane and Rosengarten's formulation. First, to what extent can we understand bone formation as an effect of culture rather than a passive unfolding of biology? Second, can we use dynamic (developmental) systems to ask better research questions and to formulate better public-health responses to bone disease?

WHY BONES?

Bones are eloquent. Archaeologists read old bone texts to find out how prehistoric peoples lived and worked. A hyperflexed and damaged big toe, a bony growth on the femur, the knee, or the vertebrae, for example, tell bioarchaeologist Theya Molleson that women in a Near Eastern agricultural community routinely ground grain on all fours, grasping a stone grinder with their hands and pushing back and forth on a saddle-shaped stone. The bones of these neolithic people bear evidence of a gendered division of labor, culture, and biology intertwined (Molleson 1994)[13]

Given that modern forensic pathologists also use bones to learn about how people live and die, it seems odd that a report from the National Institute of Medicine, presented as a state-of-the-art account of gender and medicine, deals only superficially with the sexual differentiation of bone disease (Wizeman and Pardue 2001).[14] In a brief three pages on osteoporosis, the monograph cites dramatic statistics on the frequency of osteoporosis in European and Caucasian American women and the dangers of the condition. The report offers a laundry list of factors believed to affect bone health. Jumbled together, with no attempt to understand their interrelationships or their joint, cumulative contributions to bone development and loss, are hormones, diet, exercise, genetic background, vitamin D production, and the bone-destroying effects of drugs such as cortisone, tobacco, and alcohol. In an anemic end-of-chapter recommendation the authors urge researchers to control for all of the above factors as they design their research studies. Indeed, failure to engage the task of formulating new approaches to biology prevented them from making a stronger analysis.

But osteoporosis is a condition that reveals all of the problems of de fining sex apart from gender. A close reading of the osteoporosis literature further reveals the difficulties of adding the variable of race to the mix (a point I will develop in a forthcoming paper [Fausto-Sterling in preparation]) while also exemplifying the claim that disease states are socially produced, both by rhetoric and measurement (e.g., Petersen 1998) and by the manner in which cultural practice shapes the very bones in our bodies (Krieger and Zierler 1995).

OF BONES AND (WO)MEN

The accuracy of the claim that osteoporosis occurs four times more frequently in women than in men (Glock, Shanahan, and McGowan 2000) depends on how we define osteoporosis, in which human populations (and historical periods) we gather statistics, and what portions of the life cycle we compare. The NIH (2000) defines osteoporosis as a skeletal disorder in which weakened bones increase the risk of fracture.

When osteoporosis first wandered onto the medical radar screen, the only signal that a person suffered from it was a bone fracture. Post hoc, a doctor could examine a person with a fracture either using a biopsy to look at the structural competence of the bone or by assessing bone density.

If one looks at lifetime risks for fracture, contemporary Caucasian men range from 13 to 25 percent (Bilezikian, Kurkland, and Rosen 1999) while Caucasian women (who also live longer) have a 50 percent risk. But not all fractures result from osteoporosis. One study looked at fracture incidence in men and women at different ages and found that between the ages of five and forty-five men break more limbs than women.[15] The breaks, however, result from significant work- and sports-related trauma suffered by healthy bones. After the age of fifty, women break their bones more often than men, although after seventy years of age men do their best to catch up (Melton 1988).

The most commonly used medical standard for a diagnosis of osteoporosis no longer depends on broken bones. With the advent of machines called densitometers used to measure bone mineral density (of which more in a moment), the World Health Organization (WHO) developed a new "operational" definition: a woman has osteoporosis if her bone mineral density measures 2.5 times the standard deviation below a peak reference standard for young (white) women. The densitometer manufacturer usually provides the reference data to a screening facility (Seeman 1998), and thus rarely, if ever, do assessments of osteoporosis reflect what Margaret Lock calls "local biologies" (Lock 1998, 39).[16] With the WHO definition, the prevalence of osteoporosis for white women is 18 percent, although there is not necessarily associated pathology, since now, by definition, one can "get" or "have" osteoporosis without ever having a broken bone. The WHO definition is controversial, since bone mineral density (BMD, or grams/cm^2) accounts for approximately 70 percent of bone strength, while the other 30 percent derives from the internal structure of bone and overall bone size. And while women with lower bone density are 2.5 times more likely to experience a hip fracture than women with high bone densities, high risks of hip fracture emerge even in women with high bone densities when five or more other risk factors are present (Cummings et al. 1995).[17] Furthermore, it is hard to know how to apply the criterion, based on a baseline of young white women, to men, children, and members of other ethnic groups. To make matters worse, there is a lack of standardization between instruments and sites at which measurements are taken.[18] Thus it comes as no surprise that "controversy exists among experts regarding the continued use of this [WHO] diagnostic criterion" (NIH Consensus Statement Online 2000, 3).

There is a complicated mixture at play. First, osteoporosis-whether defined as fractures or bone density-is on the rise, even when the increased age of a population is taken into account (Mosekilde 2000). At the same time, it is hard to assess the danger of osteoporosis, in part due to drug company-sponsored "public awareness" campaigns. For example, in preparation for the sales campaign for its new drug, Fosamax, Merck Pharmaceuticals gave a large osteoporosis education grant to the National Osteoporosis Foundation to educate older women about the dangers of osteoporosis (Tanouye 1995).[19] Merck also directly addressed consumers with television ads contrasting frail, pain-wracked older women with lively, attractive seniors, implying the urgent need for older women to use Fosamax (Pugh-Berman, Pearson, Allina, Zones, Worcester, and Whatley 2002).

Mass marketing a new drug, however, requires more than a public awareness campaign. There must also be an easy, relatively inexpensive method of diagnosis. Here the slippage between the new technological measure-bone density-and the old definition of actual fractures and direct assessment of bone structure looms large. Merck promoted afford able bone density testing even before it put Fosamax on the market. The company bought an equipment manufacturing company and ramped up its production of bone density machines while at the same time helping consumers find screening locations by giving a grant to the National Osteoporosis Foundation to push a toll-free number that consumers (presumably alarmed by the Merck TV ads) could call to find a bone density screener in a locale near them (Tanouye 1995; Pugh-Berman, Pearson, Allina, Zones, Worcester, and Whatley 2002).

The availability of a simple technological measure for osteoporosis also made scientific research easier and cheaper. The majority of the thousands upon thousands of research papers on osteoporosis published in the ten years from 1995 to 2005 use BMD as a proxy for osteoporosis. This is true despite a critical scientific literature that insists that the more expensive volumetric measure (grams/cm^3) more accurately measures bone strength and that knowledge of internal bone structure (bone histomorphometry) provides essential information for understanding the actual risk of fracture (Meunier 1988).[20] The explosion of knowledge about osteoporosis codifies a new disorder, still called osteoporosis but sporting a newly simplified account of bone health and disease.[21] Ego Seeman (1997) laments the use of the density measure, which, he argues, "affects the way we conceptualize the skeleton (or fail to), and the way we direct (or misdirect) our research," and "blind[s] us to the biology of bone" (510).

Weaving together these threads-increasing lifetime risk, new disease definitions, and easier measurement-produces an epistemological trans formation in our scientific accounts of bones and why they break. The transformation is driven by a combination of cultural forces (why are fracture rates increasing?) and new technologies generated by drug companies interested in creating new markets, disseminated with the help of market forces drummed up by the self-same drug companies, and aided by consumer health movements, including feminist health organizations such as the Society for Women's Research, which argue that gender-based differences in disease have been too long neglected.

Analyzing bone development within the framework of sex versus gender (nature vs. nurture) makes it difficult to understand bone health in men as well as women. Those trying to decide on a proper standard to measure fracture risk in men (should they use a separate male baseline or the only one available, which is for young, white women?) struggle with this problem of gender standardization (Melton et al. 1998). There are differences between men and women, although osteoporosis in men is vastly under studied. In a bibliography of 2,449 citations of papers from 1995 to 1999 (Glock, Shanahan, and McGowan 2000), only 47 (2 percent) addressed osteoporosis in men. But making sense of patterns of bone health for either or both sexes requires a dynamic systems approach. A basic starting place is to ask the development question.

For instance, we find no difference in bone mineral density in (Caucasian) boys and girls under age sixteen but a higher bone mineral density in males than in females thereafter (Zanchetta et al. 1995). This difference (combined with others i:hat develop during middle adulthood) becomes important later in life, since men and women appear to lose bone at the same rate once they have reached a peak bone mass; those starting the loss phase of the life cycle with more bone in place will be less likely to develop highly breakable bones. Researchers offer different explanations for this divergence. Some note that boys continue to grow for an average of two years longer than girls (Seeman 1997). The extra growth period strengthens their bones by adding overall size. Others point additionally to hormones, diet, physical activity, and body weight as contributing to the emerging sex (or is it gender?) difference at puberty (Rizzoli and Bonjour 1999).

So differences in bone mineral density between boys and girls emerge during and after puberty, while for both men and women peak bone mass and strength is reached at twenty-five to thirty years of age (Seeman 1999). Vertebral height is the same in men and women, but vertebral width is greater in men. The volume of the inner latticework does not differ in men and women, but the outer layer of bone (periosteum) is thicker in men. Both width and outer thickness strengthen the bone. In general, sex/gender bone differences at peak are in size rather than density (Bilezikian, Kurkland, and Rosen 1999).

This life-cycle analysis reveals three major differences in the pattern of bone growth and loss in men compared with that in women. First, at peak, men have 20 to 30 percent more bone mass and strength than women. Second, following peak, men but not women compensate for bone loss with new increases in vertebral width that continue to strengthen the vertebrae. Over time both men and women lose 70 to 80 percent of bone strength (Mosekilde 2000), but the pattern of loss differs. In men the decline is gradual, barring secondary causes.[22] In women it is gradual until perimenopause, accelerates for several years during and after the menopause, and then resumes a gradual decline.[23] Lis Moskilde (2000) points out that the rush to link menopause to osteoporosis has led to the neglect of two of the three major differences in the pattern of bone growth between men and women. Yet these two factors are specifically linked to physical activity, and thus amenable to change earlier in life.

Indeed, many studies on children and adolescents address the contribution sociocultural components of bone development make to male female differences that emerge just after puberty (see table 17.1). But the overwhelming focus on menopause as the period of the life cycle in which women enter the danger zone steers us away from examining how earlier sociocultural events shape our bones (see Lock 1998). Once menopause enters the picture, the idea that hormones are at the heart of the problem overwhelms other modes of thought.[24] Nor is it clear how hormones affect bone development and loss. In childhood, growth hormone is essential for long bone growth, the gonadal steroids are important for the cessation of bone growth at puberty, and probably both estrogen and testosterone are important for bone health maintenance (Damien, Price, and Lanyon 1998). The details at the cellular level have yet to be understood (Gasperino 1995).

BASIC BONE BIOLOGY

In the fetus, cartilage creates the scaffolding onto which bone cells climb before secreting the calcium-containing bone matrix that becomes the hard bone.[25] The cells that secrete the bone matrix are called osteoblasts. As they grow, bones are shaped by the strains and stresses put on them by the activity of their owner. Osteoblasts deposit matrix at some sites, while another cell type, the osteoclast, can chip away at areas of too much growth. Growing bones change shape through this give and take of osteoblast and osteoclast activity in a process called bone remodeling.[26] Long bones increase in length throughout childhood by adding on new material at their growing ends. These growth sites close as a result of hormonal changes during puberty, but bone reshaping continues over the course of a life (Currey 2002).

Bone contains two important types of tissue, which can be seen if one cuts it across the middle. The outer dense, hard layer is called compact tissue; the inner layer contains cancellous tissue consisting of a latticework of slender fibers. The fibers of this interior bone lattice fuse into longer structures called trabeculae (Latin for "small beam") that crisscross the interior of the bone. The periosteum (literally, "around the bone"), a layer of tissue through which blood vessels and nerves pass into the interior, covers the bone.

Osteoblasts clinging to the periosteum and around the trabecular struts of the bone's interior can produce new bone in both locations. Osteoblasts can also transform into osteocytes, cells found in large numbers inside the hard bone tissues (Currey 2002). Osteocytes probably play an important role in bone regeneration when they produce chemical signals that tell osteoblasts that the bone is under mechanical strain and needs to grow (Mosley 2000). Osteoblasts cannot form new bone unless the surface on which they sit is under a mechanical strain, which explains why exercise remains such an important component of bone health while weightlessness in space or prolonged bed rest result in the loss of bone thickness.[27]

Moreover, osteoblasts only add new bone on preexisting surfaces. A person with osteoporosis develops breaks in the tiny cross beams, and these widen into holes that riddle the bone's interior. A lost strut cannot be replaced because there is no old surface on which to lay down a new mineral layer. A thinning strut, however, can thicken again if the osteoblast produces more new bone than the osteoclast breaks down (Parfitt 1988; Mosekilde 2000).

Bone development, then, is profoundly influenced by what physiologists call functional adaptation. Although a great deal remains to be under stood about the biology of use and disuse, some basic principles are already evident. First, both disuse and predictable moderate use result in bone resorption and increased porosity. However, dynamic strain, that is, strain that is unpredictable and of varied impact level, can lead to a linear increase in bone mass (Mosley 2000).[28] Bones may adopt strain thresholds such that only strains above such thresholds induce new bone formation. Strain thresholds may change over the life cycle. Perhaps the decline in estrogen associated with menopause resets the threshold to a higher strain level, thus requiring very high levels of bone stress to stimulate new bone formation. Such dynamic theories allow us to understand how behavior (e.g., changing forms of exercise) and hormonal changes in the body might together produce bone loss or gain (Frost 1986, 1992).

Even such a simplified account of bone development and maintenance shows how hard it can be to understand why people in one group break their bones more often than people in another. Groups may differ in peak bone size even if bone loss later in life is the same. The trabeculae on the bone's inside might be thicker in one group than another, or the outside, compact bone layer might be thicker. There could be less bone loss or a reduction in bone turnover (the balance between osteoclast and osteoblast activity). Trabecular loss could result from thinning rather than perforation, or there could be more new bone formation in the periosteum or less resorption in the bone's interior. What is most striking about the medical literature on osteoporosis is that "whether these differences in bone size, mass, or structure, or bone turnover among ethnic groups or between men and women even partly account for the corresponding group differences in fracture rates is unknown" (Seeman 1997, 517).

Genes, of course, are involved in all of the events described in the previous few paragraphs. Rather than as causes of bone construction and destruction, however, genes are best understood as mediators, suspended in a network of signals (including their own) that induce them to synthesize new molecules.[29] The molecules they make may help to produce more bone or to break down existing bone. Either action may, in turn, be a direct effect (e.g., making a structural element such as collagen) or an indirect effect (e.g., causing the death or sustaining the life of bone making cells). Researchers have identified over thirty genes that affect bone development either positively or negatively in mice (Peacock et al. 2002), and scientists continue to identify genetic variants affecting bone density in humans (Boyden et al. 2002; Little et al. 2002; Ishida et al. 2003).

Finally, how do hormones fit into all of this? Part of the initial logic of thinking about osteoporosis as a basic biological (sex) difference between men and women derives from the observation that bone thinning increases dramatically around the time of menopause. Most thus assume that declining estrogen causes bone loss. Since estrogen codes in most people's minds as a quintessentially female molecule, it becomes extraordinarily difficult to conceptualize osteoporosis as a disease with many contributors stretching over the entire life cycle. Here, gender constructs (Fausto-Sterling 2000) combined with the profits derived from selling estrogen replacement have contributed mightily to shaping the course of scientific research in this field. Estrogen, though, is only one of a number of hormones linked to bone physiology.

At least three major hormone systems acting both independently of one another and through mutual influence regulate bone formation and loss. Fascinatingly, at least two of these operate at times through the brain and the sympathetic (involuntary) nervous system.[30] The first system includes three major hormones that maintain proper calcium levels through out the body, dipping into the bone calcium reservoir as needed.[31] The hormones (the active form of vitamin D; parathyroid hormone [PTH], which is made by a small pair of glands called the parathyroid glands; and calcitonin, which is secreted by the thyroid glands) regulate blood calcium levels and bone metabolism.[32] At low concentrations PTH maintains a stable level of mineral turnover in the bone, but at high levels it stimulates osteoclast activity, thus releasing calcium into the bloodstream.[33] Although calcitonin counteracts the effects of PTH on osteoclasts, its functions and mode of action are still poorly understood, but PTH affects bone, kidney, and intestine using vitamin D as an intermediary-a point that returns us to the contributions of sunlight and diet. Our diets and cellular machinery provide inactive forms of vitamin D, but these require the direct energy from sunlight hitting the skin to change into potentially active forms. Final transformations from inactive to active forms of vitamin D occur in the liver and kidney (Bezkorovainy and Rafelson 1996).

Although gonadal hormones-both estrogens and androgens-are clearly important for bone development and maintenance, how they regulate bone metabolism remains uncertain (Kousteni et al. 2001, 2002). Recently, some fascinating studies done on mice have suggested that both androgens and estrogens operate in a fashion unusual for steroid hormones by preventing the death of bone-forming cells without stimulating new gene activity. Whether these results will hold for humans re mains to be seen.[34] Other information from animal models suggests that bone response to mechanical strain requires the presence of an estrogen receptor on the osteoblast cell surface (Lee et al. 2003), but a clear story of the role of estrogens and androgens in bone formation and maintenance throughout the life cycle remains to be told.

Last but certainly not least a hormone called leptin, announced to the world with great fanfare in 1995 as a possible "magic bullet" for weight control (Roush 1995), also affects bone formation. Like the sex steroids, leptin works via a relay system in the hypothalamus, a part of the brain linked to the pituitary gland. Fat tissue produces leptin, which signals specialized nerve cells in the hypothalamus; these activated neurons pro duce two effects-lowering the appetite and stimulating basal metabolism (via the sympathetic nervous system). In mice, leptin has a second, apparently independent effect, also mediated through the hypothalamus and the sympathetic nervous system. Increased leptin signals nerves in the bone to depress bone formation. This presents an interpretive paradox: obesity provides some protection against osteoporosis. But the more fat cells, the more leptin is made, which in theory ought to depress bone formation. There are several possible explanations for this paradox. In mice it may be that the very overweight body becomes insensitive to its high leptin levels, just as obesity contributes to insulin insensitivity in type 2 diabetes. Or the stimulation of bone formation from the mechanical stress of increased weight might trump the effects of leptin, and/or leptin physiology in mice and humans might differ in important ways.[35]

In the next decade we will surely learn a lot more about the relationships among bone formation, leptin, and the sympathetic nervous system.[36] But we also must learn how to study the balances and interactions among all of the various factors that impinge on bone formation. How do social systems that influence what we eat, how and when we exercise, whether we drink or smoke, what kinds of diseases we get and how they are treated, and how we age, to name some most relevant to bone formation, produce a particular bone structure in a particular individual with a particular life history? To even begin to set up this problem in a manner that can stimulate future work and ultimately bring us better answers, we need to learn how to handle complex, dynamic systems. And so, finally, I turn to a discussion of two overlapping sets of ideas—developmental and dynamic systems theory.

THINKING SYSTEMATICALLY ABOUT BONE

There are better ways to think about gender and the bare bones of sex. One cannot easily separate bone biology from the experiences of individuals growing, living, and dying in particular cultures and historical periods and under different regimens of social gender.[37] But how can we integrate the varied information presented in this essay in a manner that helps us ask better research and public policy questions and that, in posing better questions, allows us to find better answers? By *better,* I mean several things: in terms of the science I want to take more of the "curious facts" about bone into account when responding to public health problems. I favor emphasizing lifelong healthful habits that might prevent or lessen the severity of bone problems in late life, but I would also like us to have a better idea of how to help people whose bones are already thin. What dietary changes, what regimens of exercise and sun exposure, what body mass index work best with which medications? How do the medications we choose work? What unintended effects do they have? Finally, *better* includes an ability to predict outcomes for individuals, based on their particular life histories and genetic makeups, rather than merely making probability statements about large and diverse categories of people.

How can we get there from here? Below, I outline in fairly general form the possibilities of dynamic systems and developmental systems approaches. Such formulations allow us to work with the idea that we are always 100 percent nature and 100 percent nurture. I further point to important theoretical and empirical work currently under way by social scientists who study chronic diseases using a life-course approach. Before turning to the specifics of bone development, let me offer a general introduction to these complementary modes of thought.

Figure 17.1 presents a visual scheme of the larger systems arena. Ludwig von Bertalanffy is usually cited as the originator of "general systems theory," a program for studying complex systems such as organisms as whole entities rather than the traditional approach of reducing the whole to its component parts (Bertalanffy 1969), but the idea of studying developmental outcomes as a result of the combined action of genes and environment began in the early twentieth century before a clear theoretical statement was achieved in the 1940s.[38]

Systems theorists also write about the brain and behavior. D. O. Hebb (1949) linked psychology and physiology by thinking about how functional cellular groups develop in the brain, thus developing a form of systems theory called connectionism. As Esther Thelen and Linda Smith put it, "the connection weights between layers—the response of the net work to a particular input—thus depend on the statistical regularities in the network's *history* of experiences" (Thelen and Smith 1998, 580). Thus an organism's current and future behaviors are shaped by past experiences via a direct effect on the strength of connections between cells in the brain.[39]

The varied systems approaches to understanding development share certain features in common. All understand that cells, nervous systems, and whole organisms develop through a process of self-organization rather than according to a preformed set of instructions.[40] The varying relationships among system components lead to change, and new patterns are dynamically stable because the characteristics of the system confer stability. But if the system is sufficiently perturbed, instability ensues and significant fluctuations occur until a new pattern, again dynamically stable, emerges. Bone densities, for example, are often dynamically stable in mid life but destabilize during old age; most medical interventions aim to restabilize the dynamic system that maintains bone density. But we really do not understand how the transition from a stable to an unstable system of bone maintenance occurs.

To address the bare bones of sex, I highlight, in figure 17.2, seven systems that contribute to bone strength throughout the lifecycle.[41] I also describe some of the known interrelationships between them.[42] Each of the seven—physical activity, diet, drugs, bone formation in fetal development, hormones, bone cell metabolism, and biomechanical effects on bone formation—can be analyzed as a complex system in its own right. Bone strength emerges from the interrelated actions of each (and all) of these systems as they act throughout the life cycle. As a first step toward envisioning bone from a systems viewpoint we can construct a theoretical diagram of their interactions. The diagram in systems approaches can be thought of as a theoretical model, to be tested in part or whole and modified as needed.[43] As ways to describe each component system using numerical proxies become available, the pictorial model can provide the framework for a mathematical model. Figure 17.2 represents one possible diagram of a life-course systems account of bone development.

This feminist systems account embeds the proposed subsystems within the

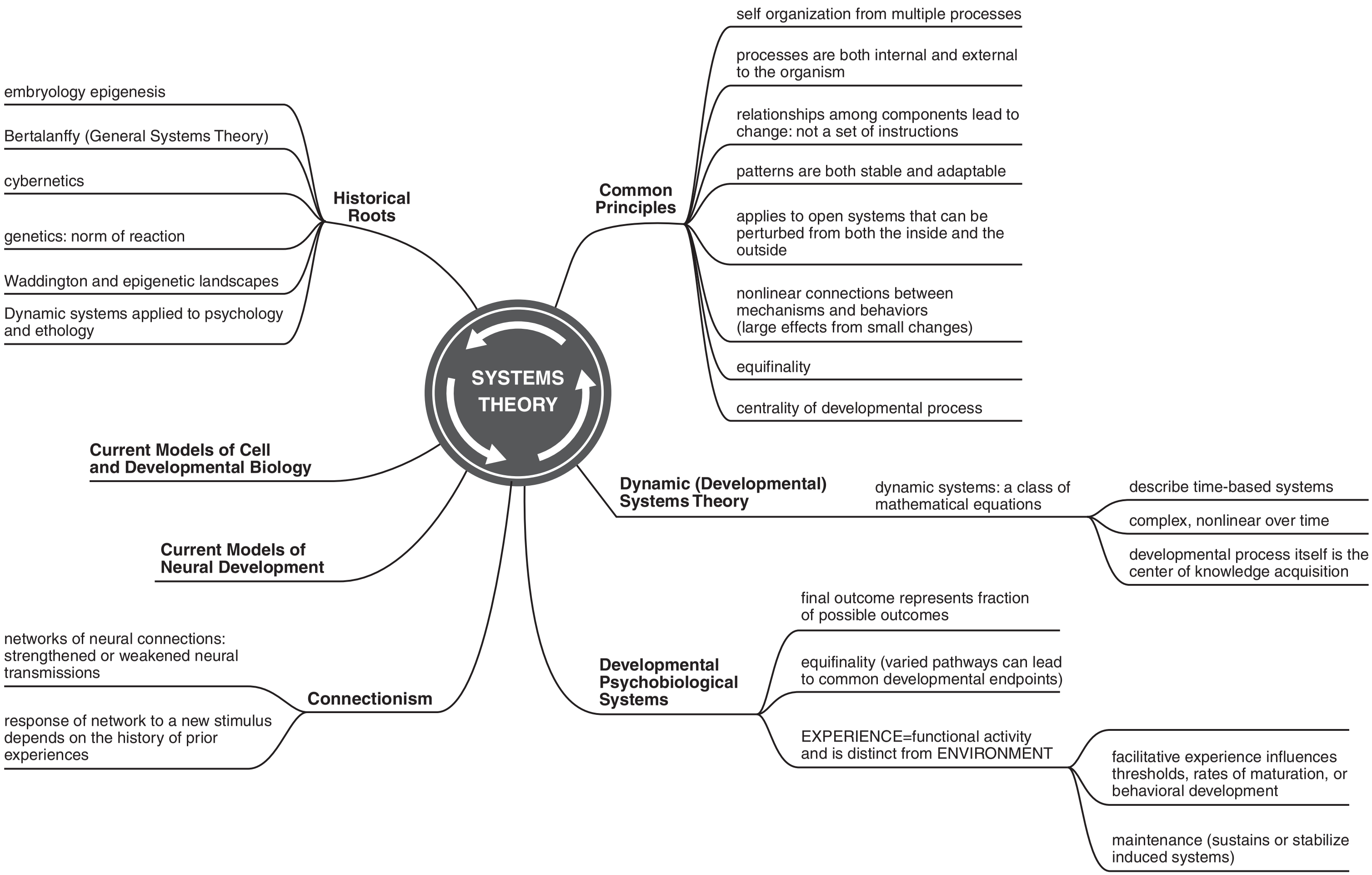

Figure 17.1 Overview of systems theories

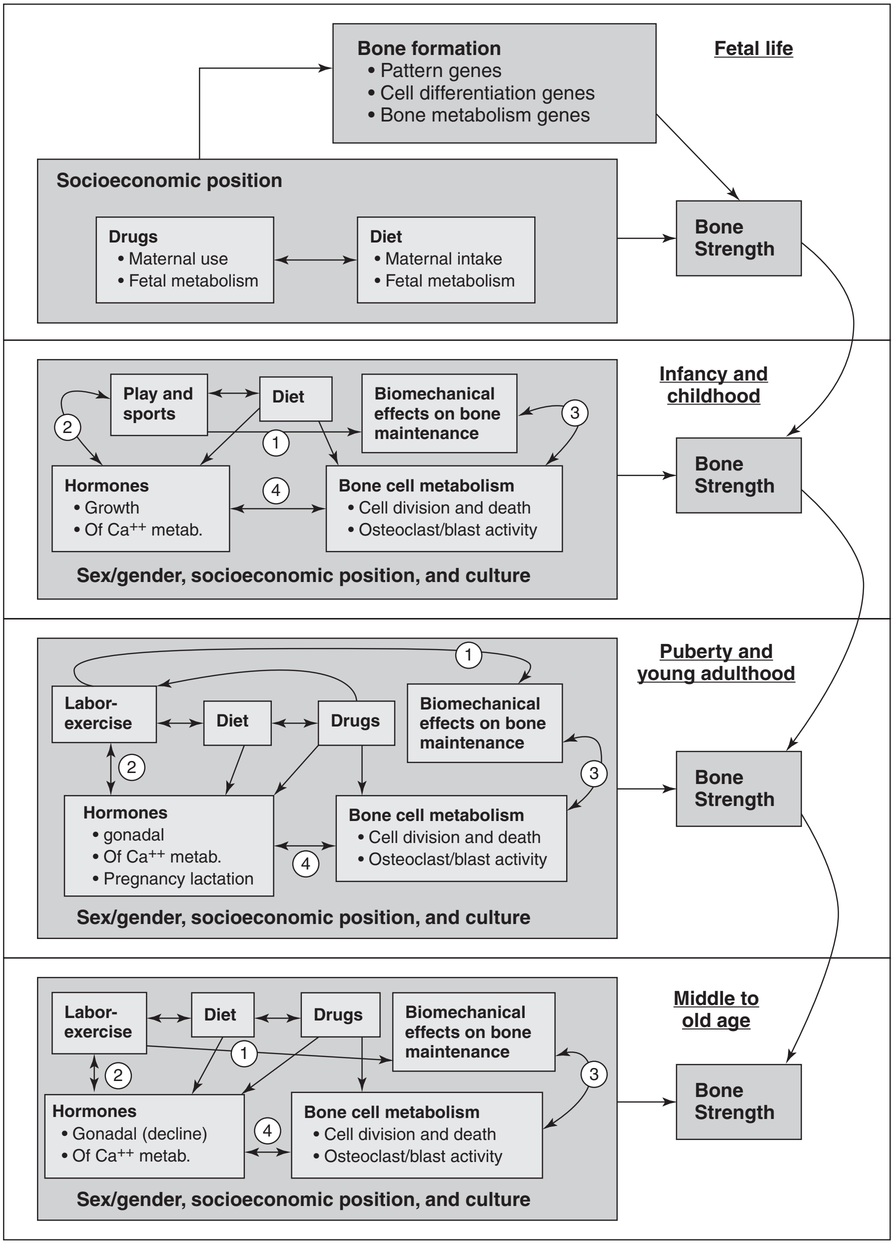

Figure 17.2 A life history–systems overview of bone development. (1) Physical activity has direct effects on bone cell receptors and indirect effects by building stronger muscles,which exert physical strain on bones, thus stimulating bone synthesis. (2) Physical activity that takes place outdoors involves exposure to sunlight, thus stimulating vitamin D synthesis, part of the hormonal system regulating calcium metabolism. (3) Biomechanical strain affects bone cell metabolism by activating genes concerned with bone cell division and bone (re)modeling. (4) Hormones affect bone cell metabolism by activating genes concerned with bone cell division, cell death, bone (re)modeling, and new hormone synthesis.

dimensions of gender, socioeconomic position, and culture.[44] Consider the diet system. Generally, of course, diet is shaped by culture and sub culture, including race and ethnicity (Bryant, Cadogan, and Weaver 1999). But gender further influences diet. For example, one study reports that 27 percent of U.S. teenage girls (compared with 10 percent of adolescent boys) who think they weigh the correct amount are nevertheless trying to lose weight (Walsh and Devlin 1998). It may also be true that there are sex/gender differences in basal metabolism rates that influence food intake.

Figure 17.2 also indicates the cumulative effects of diet on bone formation. Key events may be clustered at certain points in the life cycle.[45] For example, adolescent girls in the United States often diet more and exercise less than during earlier childhood. Diseases such as anorexia nervosa, which have devastating effects on bone development, may also emerge during adolescence. As Yoav Ben-Shlomo and Diana Kuh (2002) point out, such clustering of adverse events is common and may be thought of in terms of "chains of risk" (or benefit). In a life-course approach, prior events set the limits on later ones. If girls and women enter into adulthood with weakened bones, therefore, they can rebuild them, but their peak density may be less than if they had built stronger bones in adolescence.[46]

Alternatively, achieving a safe peak bone density might require more sustained and intense work for a person of one history compared with a person of a different history. Sex/gender, race, class, and culture also differentiate individuals by forms of play in childhood and beyond (Boot et al. 1997), by choices of formal exercise programs, and, in adulthood, by forms of labor, physical and otherwise. In analyzing the system of physical activity one again applies life-course principles by considering that what happens at any one point builds on what has gone before. Important events with regard to bone development may be clustered and interrelated. For both the diet and physical activity systems, it should be possible to design mathematical models based on some measure of bone strength that would incorporate the effects of each of these social systems on bone development through out the life cycle; once we have plausible models of each system, we can ask questions about their interactions.

The remaining four systems are often considered within the realm of biology, as if biology were separate from culture, although recent work from some medical epidemiologists challenges this distinction (Ellison 1996; Hertzman 1999; Lamont et al. 2000). The system of biomechanical effects on bone synthesis, for example, requires further investigation of all of its inputs (physical strain, activation of genes that stimulate bone cell development or death, etc. [Harada and Rodan 2003]), but these must then be studied in relationship to the gender-differentiated physical activity system. The different body shapes of adult men and women (related to hormones at puberty among other things) may also affect bone biomechanics, and we need, too, to know more about how growth and development affect the number of bone mechanoreceptors-molecules that translate mechanical stress in biochemical activity (Boman et al. 1998; Pavalko et al. 2003).

The impact of hormones on bone development and maintenance re quires research attention of a sort currently lacking in the bone literature. We need to know both about the molecular biology of hormones and bone cell hormone receptors and about life-course effects on hormone systems (Ellison 1996; Worthman 2002). Finally, genes involved in bone cell metabolism, pattern formation, hormone metabolism, drug processing, and many other processes contribute importantly to the development of bone strength (Zelzer and Olsen 2003). Understanding how they function within both the local and global (body and sociocultural) networks contributing to bone development requires a systems-level analysis not yet found in the literature.

CONCLUSION

This article is a call to arms. The sex-gender or nature-nurture accounts of difference fail to appreciate the degree to which culture is a partner in producing body systems commonly referred to as biology—something apart from the social. I introduce an alternative—a life-course systems approach to the analysis of sex/gender. Figure 17.2 is a research proposal for multiple programs of investigation in several disciplines. We need to ask old questions in new ways so that we can think systematically about the interweaving of bodies and culture. We will not lay bare the bones of sex, but we will come to understand, instead, that our skeletons are part of a life process. If process rather than stasis becomes our intellectual goal, we will improve medical practice and have a more satisfying account of gender and sex as, to paraphrase the phenomenologists, being-in-the world.

NOTES

Thanks to the members of the Pembroke Seminar on Theories of Embodiment for a wonderful year of thinking about the process of body making and for their thoughtful response to an earlier draft of this essay. Credit for the title goes to Greg Downey. Thanks also to anonymous reviewers from Signs for making me sharpen some of the arguments.

1. Munro Peacock et al. write: "The pathogenesis of a fragility fracture almost always involves trauma and is not necessarily associated with reduced bone mass. Thus, fragility fracture should neither be used synonymously nor interchangeably as a phenotype for osteoporosis" (2002, 303).
2. For example, sitting height reflects trunk length (vertebral height) vs. standing height, which reflects the length of the leg bones. These can change independently of one another. Thus height increases can result from changes in long bone length, vertebral height, or both. See Meredith 1978; Tanner et al. 1982; Malina, Brown, and Zavaleta 1987; Balthazart, Tlemani, and Ball 1996; Seeman 1997.
3. The use of racial terms such as Caucasian and others in this article is fraught. But for the duration of this article I will use the terms as they appear in the sources I cite, leaving an analysis of this problematic terminology to future publications, e.g., Fausto Sterling 2004.
4. Since a number of studies show no sex difference in hip fracture incidence between African American men and women, the "well-known" gender difference in bone fragility may really only be about white women. As so often happens, the word gender excludes women of color (Farmer et al. 1984).
5. Peacock et al. write, "Key bone phenotypes involved in fracture risk relate not only to bone mass but also to bone structure, bone loss, and possibly bone turnover" (2002, 306).
6. I am grateful to Peter Taylor for insisting that I read the work in life-course analysis.
7. Stepan 1982; Russett 1989; Hubbard 1990; Fausto-Sterling 1992.
8. I use the term experience rather than the term environment here to refer to functional activity. For more detail see Gottlieb, Whalen, and Lickliter 1998.
9. Butler 1990, 1993; Gatens 1996; Kirby 1997; Birke 1999.
10. The "rediscovery" of phenomenology and its application to gendered body image remains a fruitful arena of feminist body theory, e.g., Weiss 1999.
11. Although Thomas J. Csordas (1999) suggests that cultural phenomenological analyses transform understandings of both biology and culture, he is more concerned with how the body changes culture than vice versa. For a different anthropological point of view, see Ingold 1998.
12. Since the society receives both foundation and pharmaceutical company funding, its claim to independence requires scrutiny. The Sex and Gene Expression conferences were funded by Aventis Pharmaceuticals as well as private foundations. Industry and mainstream medical care sponsorship does not unethically direct work, but it limits the permissible ontological and epistemological approaches to the study of women's health and sex differences.

13. Perhaps because the field of archaeology is still struggling to bring gender into the fold, its practitioners often insist on the centrality of the sex/gender distinction. Yet their own conclusions undermine this dualism, precisely because they use a biological product, bone, to draw conclusions about culture and behavior (Ehrenberg 1989; Gero and Conkey 1991; Wright 1996; Armelagos 1998).
14. The validity of using bones to identity race is contested (Goodman 1997).
15. This study (cited in Melton 1988) dates from 1979, and it seems likely that subsequent cultural changes have led to different patterns of breakage; fracture incidence is a moving target.
16. Local biologies reflect local differences in biology. For example, hot flashes are far less frequent in Japan than in the United States, possibly for reasons pertaining to diet. The normalization question here is: Is it best to compare a population to its own group or some group with similar environmental and genetic histories, or to some outgroup standard?
17. These factors include: a mother having broken her hip, especially before age eighty; height at age twenty-five (taller women are more likely to break hips); extreme thinness; sedentary lifestyle; poor vision; high pulse rate; the use of certain drugs; etc.
18. One researcher states: "I think what is also of note, is that the between-center differences are greater than between-sex differences within certain centers" (Lips 1997, 95).
19. Fosamax seems to be able to prevent further bone loss in people who are losing bone and to build back lost bone at least in the hip and spine. In discussing Merck's campaign, I do not argue that the drug is useless (in fact, I am taking it!), merely(!) that drug companies play an important role in the creation of new "disease" and profit as a result.
20. "An association between the change in areal bone density and the change in fracture rates has never been documented" (Seeman 1997, 517). According to the NIH Consensus Statement Online: "Currently there is no accurate measure of overall bone strength" (2000, 5). But BMD is often used as a proxy. The National Women's Health Network cites the pitfalls of using BMD to predict future fractures (Fugh-Berman, Pearson, Allina, Zones, Worcester, Whadey, Massion, et al. 2002), but others cite a strong association between BMD and fracture rate (e.g., Melton et al. 1998; Siris et al. 2001). One overview of studies that attempted to predict osteoporosis-linked fractures with bone mineral density concluded: "Measurements of bone mineral density can predict fracture risk but cannot identify individuals who will have a fracture. We do not recommend a programme of screening menopausal women for osteoporosis by measuring bone density" (Marshall, Johnell, and Wedell 1996, 1254). See also Nelson et al. 2002.
21. For a history of the concept of osteoporosis, see Klinge 1998.
22. A secondary cause might be bone loss due to an eating disorder or a metabolic disease, or the prolonged use of a bone-leaching drug such as cortisone.
23. When I use the words men and women I refer to particular populations on which these studies were done. These are mostly Caucasian and Northern European or North American. Most of the studies have been done since the 1980s, but bone size, shape, and growth patterns would have differed at the beginning of the twentieth century compared with their appearance at the beginning of the twenty-first. I will not make these points every time I use these words.
24. So powerful is the focus on old age that the long NIH bibliography on menopause completely ignores the possible importance of pregnancy and lactation on bone development. These two processes are profoundly implicated in calcium metabolism, and if there is no effect on later bone strength it would be important to find out why. What physiological mechanisms protect the bone of pregnant and lactating women? This is an example of a biological question that lies fallow because of the focus on supposed estrogen deficiency in old age.
25. The bone matrix is made up primarily of a substance called hydroxyapatite that is mostly composed of crystalline forms of the molecules calcium phosphate, calcium carbonate, and small amounts of magnesium, fluoride, and sulfate.
26. One memory device for remembering which cell is which is to think that osteoBlasts Build bone and osteoClasts Chomp on bone.
27. Stress can be from direct impact or from tension placed on the bones by attached muscles. For more details on the importance of mechanical strain on bone development, see Skerry and Lanyon 1995; Mosekilde 2000; Mosley 2000.
28. In animal models it is possible to induce new bone formation (modeling) without first having caused bone resorption (Pead, Skerry, and Lanyon 1988).
29. One review states that mechanical receptors transform signals from deforming bones into

changes in the shape of DNA regions that regulate the activities of genes involved in bone formation. The authors write that "bending bone ultimately bends genes" (Pavalko et al. 2003, 104).

30. Physiological functions such as heart and breathing rate and energy metabolism are regulated through involuntary nerves belonging to the sympathetic and parasympathetic nervous systems. These systems balance each other out by stimulating or inhibiting various functions. They are controlled through brain centers without our having to think about them.
31. All cells, but especially nerve and muscle cells, need calcium. So bone is essential not only for structural support but also to maintain healthy calcium levels throughout the body.
32. The active form of vitamin D is 1,25-dihydroxycholecalciferol.
33. Parathyroid hormone also increases Ca^{++} reabsorption in the kidney and absorption in the small intestine.
34. The negative effects of estrogen treatment come from the hormone's more common mode of action-stimulating gene activities after binding to the nucleus. The researchers cited have a compound that has none of the gene-activity-stimulating actions but does behave like androgens and estrogens by preventing the death of osteoblasts. See also Moggs et al. 2003.
35. Ducy et al. 2000; Flier 2002; Takeda et al. 2002; Harada and Rodan 2003.
36. Leptin may also regulate the onset of puberty, thus linking gonadal hormones and the leptin hormone system (Chehab et al. 1997).
37. I found one eloquent but wordless example on the Web in an article on causes of vitamin D deficiency. The short segment titled "Insufficient Exposure to Sunlight" was accompanied by a photograph of two women, standing in the blazing sun, covered from head to toe in burkas, clearly insufficiently exposed to sunlight but not for want of being outdoors in the sun.
38. Brief histories of these ideas as well as accounts of present-day embryology, genetics, and evolution based on systems theory may be found in Waddington 1957; Kauffinan 1993; Webster and Goodwin 1996; Schlichting and Pigliucci 1998; van der Weele 1999; Oyama 2000a, 2000b.
39. The implications of these ideas for an integrative theory of the development of gender differences in behavior and psychological skills has not escaped me and is the subject of a work in progress. The explosion of knowledge about the plastic nature of brain development and an increasing understanding of neuroplasticity in adults suggests that far from being destiny, anatomy is dynamic history. A rich literature that joins mathematical models of nonlinear equations (Kelso 1995) has begun to join forces with experimental scientists who study animal behavior (Gottlieb 1997) and those who now use dynamic systems approaches to reconceptualize human behavioral development (Smith and Thelen 1993; Thelen and Smith 1994, 1998; Thelen 1995; Thelen et al. 2001).
40. Among biologists the idea that genes provide such instructions is giving way to a systems account of cell function. The metaphor of the genome (DNA) as a blueprint or set of directions for building cells and organisms is giving way to a new metaphor-genomes as parts list (Vukmirovic and Tilghmann 2000; Tyson, Csikasz-Nagy, and Novak 2002). If the genome lists only the component parts (codes for RNA and protein), the location of the assembly directions becomes uncertain: one needs to specify a cell or organism's past history and current conditions in order to predict a current developmental event accurately. Cell biologists have now turned in earnest to complexity and systems theory to help learn the rules by which organisms are assembled. (See entire December 2002 issue of *BioEssays* devoted to "Modeling Complex Biological Systems.") In another example, authors extend and twist the book metaphor: "Just as words must be assembled into sentences, paragraphs, chapters and books to make sense, vital cellular functions are performed by structured ensembles of proteins . . . not by freely diffusing and occasionally colliding proteins" (Sali et al. 2003, 216).
41. I use Peter Taylor's definition of systems as "units that have clearly defined boundaries, coherent internal dynamics, and simply mediated relations with their external context" (personal communication 2003).
42. This choice of systems emerges from the data presented earlier in this article. Since this is a model, others might argue for dividing the pie in a different way. To keep the diagram readable and the discussion manageable, I have not emphasized that the entire grouping of systems is embedded in a larger system I call "general health." There are many disease states that secondarily affect bone (e.g., kidney disease or endocrine disorders) by affecting calcium metabolism or preventing exercise. The relationships among the systems affecting bone strength would be shifted in dramatic ways worthy of study in their own right under such circumstances.

43. Choice of model has profound implications. For a discussion of a lifestyle model of disease that emphasizes individual choice vs. a "social production model," see Krieger and Zierler 1995. For an update on current theories of social epidemiology, see Krieger 2001.
44. To the extent that race is a legitimate category separate from class and culture, I will incorporate it into the bone systems story in pt. 2 of this work. For a model of social pathways in childhood that lead to adult health, see Kuh and Ben-Shlomo 1997.
45. Bonjour et al. 1997; Boot et al. 1997; Perry 1997; Wang et al. 2003.
46. For the effects of dietary calcium later in life, see Heaney 2000.

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CHAPTER 18

Constructing Gender from the Inside Out: Sex-Selection Practices in the United States

Rajani Bhatia

In the July 2010 issue of the *Atlantic*, Hanna Rosin published a provocative article proclaiming "the end of men." Among the evidence provided—increased rates of female employment and their higher levels of education—Rosin highlights girl preference data stemming from U.S. sex-selection practices. Her "unambiguous proof" of a significant cultural transformation, which she purports has left boys and men in the dust, is that a majority (75 percent) of those participating in a clinical trial of one new sex-selection method known as MicroSort sought girls.[1] Rosin neglects to mention that MicroSort is technologically more effective at raising a couple's chances of producing a girl rather than a boy, because its sperm-sorting technique produces purer samples of X—rather than Y—chromosome-bearing sperm. It would follow, then, that couples preferring boys would less likely utilize this method, but would turn instead to a second, also new, sex-selection method—preimplantation genetic diagnosis (PGD)—that, unlike MicroSort, does not carry a technical bias toward the production of girls over boys. Rosin, however, provides no data from clinics offering PGD. And yet, in spite of these oversights, I will be arguing in this article that recent sex-selection practices involving new technologies in the United States do mark a significant socio-cultural-technical shift that feminists should be paying attention to—even if they do not portend the hyperbolic "end of men."

For more than a decade now, mass print and television media have been heralding the development and marketing of new technologies as the answer to a long quest for scientifically proven methods for selecting the sex of a child. MicroSort and PGD are new methods of sex selection used in conjunction with assisted reproduction such as in vitro fertilization (IVF) or intrauterine insemination (IUI). MicroSort involves sorting sperm based on the chromosomes determinative of sex. PGD is a diagnostic technology that involves testing embryos produced through IVF for the characteristic of sex and then preselecting embryos for implantation based on sex preference. MicroSort and PGD both circumvent the politically contentious abortion issue because they are applied before pregnancy (although PGD may involve the discarding of viable embryos). The importance of this feature in the U.S. context cannot be overstated, and it is precisely what makes these technologies so marketable. At the same time, prospective customers of sex selection increasingly have found each other on the Internet, developing a collective identity based on their desire for a child of a particular sex. Patient/consumer activism via the Internet provides sympathetic, self-help spaces that allow individuals to express their intention to preselect their offspring's sex or their disappointment at birthing a child of the "wrong sex." Taken together, these developments signal a new era in which there is a potential for the practice of sex selection in the United States to become increasingly normalized.

In the late 1970s, the development of prenatal diagnostic technologies announced a first generation of medicalized sex-selective methods. Ultrasound scanning and amniocentesis to detect sex, if followed by sex-selective abortion, however, remains highly controversial and presents a dilemma for prochoice feminists, who are wary of endorsing any restrictions on abortion. Now, much has changed in the move from first- to second-generation sex-selection technologies such as MicroSort and PGD. Whereas the use of prenatal diagnostic technologies for sex selection was a perhaps unforeseen consequence of the increased medical surveillance of pregnancy, second-generation sex-selection technologies became possible because of the medicalization of infertility since the 1970s. First-generation sex-selection technologies afforded a "deselection" of sex, which through its active negation or choice against a particular sex via abortion carries negative connotations; second-generation technologies allow for sex "preselection," which seems to imply choice in a more positive sense, that is, choice "for" rather than "against." Such positive choice is illusory, as a choice "for" a boy necessarily involves a choice "against" a girl. Nevertheless, second-generation technologies benefit from association with assisted reproduction as opposed to abortion. Fertility clinics can use demand for sex selection to attract a wider range of customers who are not infertile.

This article is a critique of the practice of sex selection and an argument for the significance of that critique for feminist theory. Through a rhetorical analysis of sex-selection discourses by marketers, the medical establishment, and private consumers, I contribute to theorizing the social relations of technology and resist the mass media representation of sex selection as an inevitable consequence of "freedom of choice." I hope to persuade U.S.-based feminists of the growing relevance of the issue to feminist concerns. My entrée into the issue of sex selection came from listening to first-hand accounts of women's health activists in Mumbai who had since 1985 organized a campaign against sex-selective abortion. I thus came to view sex selection as a form of gender-based violence. Sex selection is now a transnational feminist issue, but I hope to make clear why new technologies and practices of sex selection should be of grave concern to U.S. feminists and why we also have a stake in how new technologies are introduced, marketed, and used. In the United States, it is presumed, sex selection does not constitute a gender discriminatory practice because of the lack of perceptible son preference. Libertarian feminist perspectives that critique government intrusions into matters considered private reduce the issue to a question of "freedom of choice." Yet we need to look beyond the individual level of consumer choices to grasp more fully the implications of sex selection in the United States.

My approach to this issue combines several bodies of feminist inquiry: sex and gender; reproductive rights; cultural difference; and gender, health, and illness. My analysis puts these discursive fields into conversation in order to arrive at a broader framing that highlights the issues at stake for U.S. feminists and their allies. While focusing on sex selection in the United States, I intentionally hold in view the context of sex selection in India for two reasons. First, my refusal to separate the Indian and U.S.

contexts contrasts with popular, medical, and bioethical discourses that situate sex selection in India (or, more generally, Asia) as a polar opposite to U.S. practices. Viewing Eastern and Western contexts as oppositional and unequal immunizes U.S. sex selection from interrogation on cultural grounds. Second, by merging U.S. and Indian contexts, I aim to seek new directions for a feminist politics of reproduction that can bridge a number of increasingly untenable binaries: (over)fertility/(in)fertility, contraception/conception, developing/developed, irrational/rational, modern/postmodern, and population control/individual control. The discussion begins with a short background of the factors that drive the gradual normalization of sex selection in the United States. This article then explores five main issues: constructing gender *from the inside out*, that is, engaging U.S. sex-selection practices in the meanings of sex and gender; the right to have versus the "right" to choose children; making parents; cultural double standards concerning sex selection; and sex selection as a potential case study of new forms of medicalization. Ultimately, I argue that the normalization of U.S.-based sex-selection practices comes with high stakes. These include the reinforcement of sex and gender binaries, the undermining of the very meaning of reproductive rights, and the construction of "Third World women" as the site of irrational practices of sex selection.

FACTORS DRIVING THE NORMALIZATION OF SEX SELECTION IN THE UNITED STATES

Three main coinciding factors drive the trend toward sex selection in the United States. They are the emergence of a second generation of medicalized sex-selection technologies performed prior to pregnancy, the increasing publicity about these technologies in the popular media, and the formation of active Internet support groups for individuals who desire to preselect the sex of their children.

New Prepregnancy Technologies

Two forms of sex-selection technologies were developed in the 1990s: MicroSort, a sperm-sorting method, and PGD, a genetic test performed on embryos prior to their transfer into the uterus of a woman during IVF. MicroSort operates by sorting and separating a man's sperm into X-bearing sperm that produce girls and Y-bearing sperm that produce boys. Developed originally by the U.S. Department of Agriculture to sort bull sperm, the method underwent a trial in humans between June 1994 and March 2010. The Genetics and In Vitro Fertilization (GIVF) Institute in Virginia, which holds an exclusive license to apply the technique in humans, has applied to the Food and Drug Administration (FDA) for approval of the technique and currently awaits determination by the FDA of its application.[2] During the trial, the GIVF Institute used two laboratories for sorting sperm, one in Virginia and the other in California. A number of collaborating assisted reproductive technology (ART) centers around the country provided the method, using frozen, sorted sperm samples obtained from the two laboratory sites. The MicroSort process involves first applying a dye to sperm and then sending it through a flow cytometer device that causes the dyed sperm to fluoresce. The device then detects and quantifies the amount of fluorescence (more dye binds to X-bearing sperm). Subsequently, the device deflects X- from Y-bearing sperm to produce the sorted samples.[3] A trial participant who would like a girl, for example, used the X-bearing sorted sample of sperm in conjunction with ART methods such as IUI or IVF to become pregnant. Among those who did get pregnant, GIVF claimed increasing the chances for a girl to 91 percent and for a boy to 76 percent.[4] In the trial, MicroSort cost $3,400 for the sperm-sorting procedure, which did not include the additional necessary costs of ART.[5] Most women attempted MicroSort on average three times before either getting pregnant or dropping out of the trial. Recruitment ads for the trial appeared in the *New York Times* Sunday magazine and in airline in-flight magazines.[6]

First tested on humans in 1990, PGD came into more routine use by the end of that decade among infertile couples undergoing IVF in order to screen for disease-causing chromosomal arrangements or genetic sequences. The test involves extracting a single cell from each embryo in a batch created via IVF. Thus, if using PGD to select a girl, only embryos with XX chromosomes would be implanted in a woman's body. Combined PGD and IVF cost around $20,000. PGD is highly accurate in determining the sex of tested embryos, although pregnancy rates using IVF are variable. Many ART clinics openly advertise sex-selection services for nonmedical reasons.[7]

Functioning as a trade association for the ART industry, the American Society of Reproductive Medicine (ASRM) issues policy recommendations on the ethical use of technologies, but clinics are not required to follow them. In 1999, the ASRM Ethics Committee issued a report stating that PGD solely for sex preference (a.k.a. "nonmedical" sex selection) should be discouraged because of "risk of unwarranted gender bias, social harm, and the diversion of medical resources from genuine medical need." Sex selection is sometimes practiced on medical grounds to detect sex-linked diseases such as hemophilia and Duchenne muscular dystrophy. In spite of the ASRM opinion and because of lack of regulation of the ART industry, clinics have in growing numbers begun to cash in on the lucrative sex-selection market by offering PGD for sex selection. A feature article on sex selection in *Spirit,* Southwest Airlines' in-flight magazine, reported that fertility doctor Jeffrey Steinberg quadrupled his business after offering PGD for sex selection. In fall 2006, the Genetics and Public Policy Center concluded that 42 percent of 415 clinics surveyed offered PGD for nonmedical sex selection.[8]

Popular Media and Marketing

Since 1998, articles on the new sex-selection technologies have appeared widely in popular media, including the *New York Times Magazine,* the *Washington Post, Newsweek, Vogue, Fortune, Time,* an *Oprah* show, and a CBS News program. I examine the ways in which mass media abet normalization of sex selection with a critical reading of two texts: a *Newsweek* magazine cover story and a CBS News *60 Minutes* report. I argue that the main effect of this coverage is a decontextualized "freedom of choice" narrative that evades relevant social issues.

Titles such as "Brave New Babies" (*Newsweek*) and "Choose the Sex of Your Baby" (*60 Minutes*) introduce the issue of sex selection to popular audiences. Popular media dramatize a fundamental transformation in reproduction signaled by the new sex-selection technologies. They sensationalize the transformative possibilities of the technologies at the individual level. Claudia Kalb writes in the *Newsweek* story, "The brave new world is definitely here. After 25 years of staggering advances in reproductive medicine . . . technology is changing baby-making in a whole new way. No longer can science simply help couples have babies, it can help them have the kind of babies they want." In a similar vein, *60 Minutes* reports, "Want to design the perfect baby? It's not as farfetched as you may think. . . . A new technology is helping couples manipulate Mother Nature in their favor."[9] Sex-selection technologies are posed as an "enhancement" of personal liberty and a win for science in a struggle to control nature. Both *Newsweek* and *60 Minutes* begin and end with case studies of couples who used the technologies to fulfill personal "dreams." We hear of Sharla and Shane Miller, who used PGD, and of Mary and Sam Toedtman and Lizette Frielingsdorf, who were enrolled in the MicroSort trial. The Miller, Toedtman, and Frielingsdorf families each had three boys before attempting sex selection for a girl.[10] The desire to select sex after three children of the same sex is represented as rational rather than frivolous or indulgent.

By highlighting these stories, popular discourses support medical discourses that define sex-selection technologies as socially acceptable. According to Marcy Darnovsky, feminist science scholar and associate executive director of the Center for Genetics and Society, the GIVF Institute in Virginia, which ran the clinical trial on MicroSort, appears to have played a large role in popularizing the concept of "family balancing." This notion presupposes that families without children of both sexes are "incomplete" or "unbalanced." Recruitment ads for the MicroSort trial marketed the sex-selection technology for aiding in "family balancing" or "gender variety." In order to participate in the MicroSort trial, a couple must already have children of a sex opposite to that desired. Initially Dr. Jeffrey Steinberg's fertility clinics also restricted access to PGD for sex selection to those who used it for "family balancing" but gave this up because of high demand among couples without children.[11] Popular media does not mention, let alone scrutinize, the preferences of families who clearly desire to select sex apart from "family balancing" reasons.

The popular media also obscure the fact that the majority of individuals who attempt these technologies do not achieve a pregnancy, let alone the birth of a child of the desired sex. Both *Newsweek* and *60 Minutes* end by recounting the happiness and joy of the parents in the successful cases, using melodramatic narratives of individual healing and the overcoming of obstacles in order to achieve a happy ending. Rather than present the cases as oddities, *Newsweek* and *60 Minutes* bolster the notion that these individual stories are common, with suggestions of high demand for the technologies. Popular media representations of sex selection do include conflicting opinions about the practice but downplay the concerns of medical professionals or medical ethicists in comparison with the narratives of scientific and personal or family success. There are no personal stories of individuals adversely affected by pressures to select the sex of their children nor are there contrary opinions from members of civil society.

Mass media discourses treat sex selection as similar to other kinds of new medical enhancement drugs or treatments for behavior, cognition, athleticism, and so forth. Presumably, as long as no harm is done to anyone else, individuals have the right to alter or enhance themselves or their lifestyles. In the case of sex selection, popular media assume that the right to have a particular kind of child simply extends from the right to have children, at least for those who can afford the technologies. *Newsweek* and *60 Minutes* do not question the implications of stratified use. They do not ask how the treatment of nonmedical preferences of a few affects access to the medical treatment needs of many. They do not ask whether assisted reproduction clinics, as they increasingly vie to attract wealthy, fertile consumers, will only deepen racial and socioeconomic disparities in access to fertility technologies for those who are infertile.

Although they mention the high price tag for the technologies and the lengthy, cumbersome procedures involving assisted reproduction, the articles neglect to mention health risks posed by PGD or discuss how the risk/benefit profile of undergoing sex selection and assisted reproduction technologies might change for nonmedical uses by fertile couples. Presumably, acceptable levels of risk should be lower for "healthy" (that is, fertile) users of the technologies, wishing to select nonmedical traits in their offspring. Yet popular media depictions do not scrutinize safety and related regulatory issues.

In sum, the mass media celebrate the arrival of new sex-selection technologies as a revolution in the way people have children. The theme of scientific "technological breakthrough" surfaces prominently in these mass media depictions of current and future practices and prospects of sex selection. Replete with personal stories of those who have used the new technologies successfully, media representations stress the individual benefits of the technologies. Media stories do highlight controversy, yet, in spite of the inclusion of critical voices on nonmedical sex selection, the media do not investigate the issues raised. It portrays sex-selection practices, for better or worse, as a fait accompli. In these ways, the mass media drive the momentum behind the increasing normalization of sex selection in the United States.

Internet Support Groups

The development of Internet support groups has also increased public awareness of sex selection. Jennifer Merrill Thompson prefaces her book, *Chasing the Gender Dream: The Complete Guide to Conceiving Pink or Blue with the Latest Sex Selection Technology and Tips from Someone Who Has Been There,* with a description of her interaction with an online virtual community and friends "who had a similar obsession."[12] Several Internet Web sites provide forums where those who desire sex-specific children can meet and support each other. These include the "Determining Sex" and "Disappointed about Gender" bulletin boards at babycenter.com; the "Gender Determination" board at ivillage.com; and various forums at In-gender. com including one on "Gender Disappointment" that stipulates, "This is a support forum, not a debate forum. Any comments along the lines of 'you should just be glad you can have children when others can't' or 'you ought to be happy with what you have' will be swiftly deleted without apology."[13] The self-help and support provided by these Internet communities do much to bolster the social legitimacy of sex-selection practices. In an article in the *New York Times* on sex selection, Lisa Belkin comments on Internet support forums:

> These women do not question whether the sex of a child should matter. They take it as a given. Just as it is different being a boy than a girl, they say, it is equally different being a parent to a boy than to a girl. Yes, they understand that the health of a child is most important, but that does not mean that everything else is unimportant. They talk about sex selection as if it were the norm, their right. And all their talk goes a long way toward making it so.[14]

In these ways, Internet support forums do much not only to popularize and spread information on second-generation sex-selection technologies but also to demonstrate demand for them.

The advent of second-generation technologies alongside the increased presence of sex selection in popular media and Internet support communities signal the increasing normalization of sex selection in the United States. That two separate methods of prepregnancy sex selection appeared at more or less the same moment may have been a factor in the normalization process. Although different in design and function, both MicroSort and PGD have been able to make plausible claims of ethical acceptability, compared to first-generation sex-selection methods utilizing abortion. Also, competitive assertions of superiority undoubtedly increased the visibility of both. (PGD wins on relative efficacy, because MicroSort merely raises one's chances of achieving a child of desired sex while PGD virtually guarantees it, if one can get pregnant and carry to term. MicroSort, however, wins for limiting intrusiveness and the production of ethically problematic objects such as undesired embryos.) The push and pull of such assertions against one another has not only shaped the direction of ethical debate, but seems to have emboldened the development of both. While the FDA has a hand in the outcome of MicroSort use in the United States, PGD use for nonmedical sex selection continues to expand. Outside of the minimal reporting requirements of the Centers for Disease Control and Prevention for IVF success rates, no federal regulatory mechanisms have extended their reach over the primarily self-regulating U.S.-based ART clinics.

Moreover, regardless of the still-pending FDA determination on MicroSort, GIVF seems to have extended the commercial life of its experimental sperm-sorting method through the "outsourcing" of MicroSort laboratories to Mexico. Even though a recently appearing MicroSort statement posted on its international Web site (microsort.com as opposed to microsort.net) carefully explains that "MicroSort is not for sale in the United States" and "In the United States, MicroSort is available only to qualified participants through a clinical trial," U.S. clients can now easily access the method outside the jurisdiction of the FDA in Mexico for a sort fee significantly less (nearly one-third) than in the United States.[15] This news created a buzz of activity on In-gender.com after someone using the site name "Diego" first posted this information on May 18, 2009. Among the responses, "I Luv My Kids~~~" posted on September 28, 2009:

> really wow!!!where is it in mexico again and what are hotel costs down there . . . maybe there is [sic] resorts where you can get a package to stay down there awhhh it would be a nice get away hubby,sand,beach my dream of dd [darling daughter]coming true. . . .[16]

And while sex-selection practices via MicroSort may move across the border to Mexico where they can circumvent FDA restrictions, some U.S.-based clinics using PGD technologies increasingly cater to an international clientele. Touting itself as "the world's largest and most successful gender selection program," the Fertility Institutes in Encino, California, utilize a number of advertising techniques to offer PGD to reproductive "tourists" from outside the United States, thereby establishing itself as another new node amid circuits of travel in the transnational reproductive economy. Clearly, the transnational implications of U.S. sex-selection practices need further study.

I turn now to a more theoretically rooted discussion for scholars and activists who take into account social justice frameworks at least as much as they do individual liberties and whose work can benefit from an increased attention to sex selection.

CONSTRUCTING GENDER FROM THE INSIDE OUT: REINFORCEMENT OF SEX AND GENDER BINARIES

Controversy around sex selection stems partly from public discomfort with human intervention into nature or "divine will." For example, an article by Tanya Wenman Steel on MicroSort in *Child,* a magazine for parents, reports on the case of a Catholic couple who successfully conceived a girl after three tries using the sperm-sorting method. In answer to the moral dilemma of whether sex selection represents a form of "playing God," the mother replied, "God has made this technology available and he'd want us to use it."[17] While second-generation methods of sex selection might defy notions of sex as a preordained trait, they do not challenge the dominant construction of sex and gender as dualistic categories. This section argues that although sex has increasingly become biomedically alterable (at least within the confines of the female/male binary), gender becomes more determined by body geography. Even consumers with feminist impulses, who desire to rear empowered girls and women, base conceptions and the possibility of girlhood within a rigidly defined, unambiguous female body. In this way, sex-selection practices represent a kind of body politics in which girlhood becomes geneticized, and sex and gender binaries are reinforced.

Evidence that sex-selection practices reinforce the gender binary can be found through popular media on the subject and Internet support Web sites, which reveal that the motivations of those who desire to choose the sex of their children hinge on common gender stereotypes. The *CBS News Early Show* quoted Monique Collins, a participant in the MicroSort trial: "I wanted to have someone to play Barbies with and to go shopping with; I wanted the little girl with long hair and pink and doing fingernails."[18]

Contemplating sex selection, Steel writes:

> I knew I was in trouble when I bought the pink tutu. This piece of flowery femininity had caught my eye as it hung in the window of a children's clothing store. I thought about it for weeks before buying it for a friend's daughter. But for whom was I really buying it? For my friend's little girl or for myself, to feed an unspoken hunger within? Four years ago, I conceived (naturally) twin sons. Now that they're "big boys," my house has become a shrine to Power Rangers. We have enough Matchbox cars to fill a real garage. When I watch the boys interacting with female playmates, I fantasize about raising a daughter myself.[19]

After achieving her "gender dream" of having a girl through MicroSort, Jennifer Thompson concludes her guide to sex selection, "The first time I went to purchase a little dress and hairbows for my daughter, I almost welled up with tears."[20] *New York Times* reporter Lisa Belkin sums up postings to Internet sites by those desiring girls, "They speak of Barbies and ballet and butterfly barrettes. They also describe the desire to rear strong young women."[21] These examples raise a number of questions related to how one "does" gender through sex selection, even understandings of gender apparently motivated by feminist ideas of strong girls and women. Although the use of sex selection does not necessarily foreclose raising children in nonnormative gendered ways, anecdotes in popular media suggest that gender expectations and desires of parents are fueled by normative stereotypes of gender.

Furthermore, discourses around sex selection reinforce the idea of sex as a foundational category of gender, because the choice between blue and pink ultimately translates to the chromosomal options of either XX or XY. Consumers of second-generation sex-selection technologies not only seek to choose the sex of embryos, but they also do so on the basis of an imagined already gendered child. In effect, consumers choose the sex of babies as a guarantee of child gender, thereby re-affixing gender to sex. Sex selection seems to lock in or fuse societal or parental gender expectations and desires at the site of the sexed infant body, fetus, embryo, or sex chromosome of sorted sperm.

How should current sex-selection practices in the United States affect the way theorists have conceptualized sex and gender? Early feminist theories constructed a liberatory version of a sex/gender binary in order to oppose arguments that related women's oppression to a fixed biological destiny of females and to highlight the social construction of gender. New forms of activism and theory since the 1990s have extended construction arguments to the category of sex and in the process have reconceptualized sex as socially constructed. Anne Fausto-Sterling and Judith Butler are among the more influential theorists who have questioned the sex/gender binary. Illuminating the highly integrated social constructions of sex, gender, and sexuality, their analysis is closely connected with queer and lesbian/gay/bisexual/transexual/intersex (LGBTI) activism and movements. Fausto-Sterling explains, "Our bodies are too complex to provide clear-cut answers about sexual difference. The more we look for a simple physical basis for 'sex,' the more it becomes clear that 'sex' is not a pure physical category. What bodily signals and functions we define as male or female come already entangled in our ideas about gender."[22] Similarly, Butler contends,

> And what is "sex" anyway? Is it natural, anatomical, chromosomal, or hormonal, and how is a feminist critic to assess the scientific discourses which purport to establish such "facts" for us? . . . If the immutable character of sex is contested, perhaps this construct called "sex" is as culturally constructed as gender; indeed, perhaps it was always already gender, with the consequence that the distinction between sex and gender turns out to be no distinction at all.[23]

These ideas radically altered former feminist theorizations that posited gender as a social construct against the "biologically determined" category of sex. Patient rights-based activism by Suzanne Kessler and the Intersex Society of North America provides an additional basis for theoretical explorations into the social construction of sex. Just as LGBTI activisms required feminists to rethink the distinction between sex and gender, it might now be the time to engage practices of sex selection in our theoretical explorations into sex and gender. At its best, sex selection in the gene age promises a denaturalization of sex, the ultimate ability of humans to self-determine biologies and thereby identities, subjectivities, and destinies. Yet, we know that the real world makes this possibility contingent upon social and cultural power dynamics and inequalities. The use of PGD for sex selection in the United States and the possibility that MicroSort may become widely available appear more likely to represent a renaturalization of gender in sex that undermines decades of feminist theoretical work insisting on the social construction of gender. Moreover, the potential to abuse these technologies in gender discriminatory ways warrants scrutiny by feminists.

The Right to Have versus the Right to Choose Babies Feminist inquiry has long addressed issues related to reproduction, such as pregnancy, abortion, adoption, fertility, sexuality, conceptive or contraceptive technologies, and pronatal or antinatal population policies. Many positions characterize the debate. Feminists have both celebrated and denigrated motherhood, both embraced and repudiated technologies in their visions and movements for self-determination, liberation, and/or justice. Here I consider how feminists concerned about reproductive rights and justice might think about sex selection. In spite of real differences, feminist scholars and activists have to a large extent reached consensus in support of a reproductive right for individuals to have or not have children. The International Conference on Population and Development (Cairo, 1994), in which feminist advocates from all over the world participated in unprecedented levels, produced a concluding document that codifies "the basic right of all couples and individuals to decide freely and responsibly the number, spacing and timing of their children and to have the information and means to do so" (Article 7.3).[24] It makes no reference to an individual's right to choose *characteristics* of children, nor is this anywhere implied. Yet, the availability of sex selection in the United States and elsewhere bolsters extreme libertarian perspectives on reproductive rights that stray a long way from this meaning.

For example, bioethicist John Robertson views the selection of genetic characteristics in offspring as an extension of an individual's right to procreate:

> Some right to engage in genetic selection would also seem to follow from the right to decide whether or not to procreate. People make decisions to reproduce or not because of the package of experiences that they think reproduction or its absence would bring. In many cases, they would not reproduce if it would lead to a packet of experiences X, but they would if it would produce packet Y. Since the makeup of the packet will determine whether or not they reproduce, a right to make reproductive decisions based on that packet should follow. Some right to choose characteristics either by negative exclusions or positive selection, should follow as well, for the decision to reproduce may often depend upon whether the child will have the characteristics of concern.[25]

Significantly, Robertson supports selection of nonmedical genetic characteristics in children as well as human reproductive cloning, basing his positions on a liberal and individualist view of reproduction. Although Robertson presents the right to choose characteristics of children as a logical extension of the right to decide whether to have children, his "freedom of choice" paradigm, like media portrayals, masks a number of social issues related to reproduction.

First, Robertson's notion of procreative liberty ignores the ways in which power relations stratify the reproduction of different groups of people. In *Conceiving the New World Order: The Global Politics of Reproduction,* Faye D. Ginsburg and Rayna Rapp put forth a definition of stratified reproduction as "power relations by which some categories of people are empowered to nurture and reproduce, while others are disempowered."[26] Given that second-generation practices of sex selection require assisted reproduction, sex selection is an expensive practice accessible only to wealthy women. However, the practice of sex-selective abortion continues as the low-income option. In this way, we see a growing trend of stratified practices of sex selection within overall stratified practices of reproduction. The possibility or indeed likelihood that moral distinctions may be made according to type of technology used, that is, assisted reproduction (read: good sex selection) versus abortion (read: bad sex selection), may unwittingly grant antichoice activists another opportunity to gain the upper hand in questions of morality that permeate the U.S. abortion debate. Indeed, U.S. Representative Trent Franks (R-AZ) proposed antichoice laws in 2008 and 2009 at the federal level that would prohibit sex-selective abortions on the grounds that such a law would deter sex discrimination.[27]

Second, Robertson promotes a market approach in which "freedom of choice" is seen to be the ultimate good regardless of the context of the "choices" or the differential way in which women can participate in this "choosing" depending on their social location. Gail Weiss, who provides one of the few feminist perspectives on sex-selective abortion stemming from the United States, argues that "the decision to perform SSA [sex-selective abortion] is . . . almost never made by the pregnant woman alone." Weiss analyzes sex-selective abortion from the standpoint of family and community practices that "make it appear to be a desirable (and, for many, the only viable) option."[28] Correspondingly, an awareness of the ways in which context determines women's choices has led advocates against widespread sex-selective abortion of female fetuses in India to insist that any regulatory measure designed to curb the practice must not punish the woman who undergoes the technology.

Not only does context matter for those groups of relatively disadvantaged women facing multiple constraints on their decision-making power, but also feminist sociologists and disability scholars increasingly point out that the commercialization of reproduction can circumscribe choice even for those who have financial access to expensive technologies. Sociologists Anne Kerr and Sarah Cunningham-Burley note that as new technologies become operationalized in service of existing social conventions that confine and restrain the abnormal, they represent a limitation rather than an expansion of real choice for individuals: "Bodies remain docile when the options for their reinvention follow the conventions of beauty and health; and reproduction remains a fateful process because of the very ability to eliminate the undesirable in favor of a norm." Disability scholar Shelley Tremain elaborates on this theme through the now widely practiced use of prenatal screening technologies. Tremain argues that "the government of impairment in utero is inextricably intertwined with the government of the maternal body." Rather than simply expanding choice, Tremain interprets prenatal screening technologies as effectively limiting "the field of possible conduct in response to pregnancy." Silja Samerski similarly critiques prenatal genetic counseling as a form of "professionally imposed self-determination" that "does not empower patients" but rather presents them with a "fiction of choice."[29] These perspectives provide a counterpoint to the simplistic "technology as progress and expansion of choice" messages expressed in both popular media and libertarian statements about reproductive technologies.

Some critics of reprogenetic technologies find the prospect of choosing characteristics through negative or positive selections disturbingly reminiscent of eugenics and tending toward the commodification of children. In a commentary on sex selection published in 2002 in the *Atlantic Monthly,* Margaret Talbot writes,

> It might sound harmless enough, maybe even kind of cute—this impulse to pick and choose, pink or blue. But if we allow people to select a child's sex, then there really is no barrier to picking embryos—or, ultimately, genetically programming children—based on any whim, any faddish notion. . . . A world in which people (wealthy people, anyway) can custom-design human beings unhampered by law or social sanction is not a dystopian sci-fi fantasy any longer.[30]

Feminist critics of population control, women of color advocates of reproductive justice, and disability scholars, in particular, have drawn parallels between past and present forms of eugenics in order to emphasize the recurrent devaluation of the reproduction of marginalized groups in dominant popular discourses.[31] In contrast to Robertson's notion of reproductive rights, feminist theorizations on reproduction have a long tradition of analysis of social (rather than exclusively individual) aspects of reproduction voiced in critiques of stratification, choice, and eugenics. Applying these perspectives to a discussion thus far dominated by medicine, professional bioethics, and popular media can productively ground limited and erroneous notions of rights and choice that accompany the conversation about U.S. sex selection.

CHOOSING BABIES, MAKING PARENTS

Feminist theories of reproduction increasingly have moved from the limited notion of individual agency in "reproductive choice" to a broader view of reproduction as a complex social process involving what women's health and science studies sociologist Adele E. Clarke calls "messy, 'sticky' and 'distributed' " agencies among different human and nonhuman actors.[32] Given that the second generation of sex-selection technologies can be viewed as one outcome of ARTs, an analysis of the current trends in sex selection can derive much from Charis Thompson's *Making Parents: The Ontological Choreography of Reproductive Technologies*. Thompson uses ethnographic research involving patients both inside and outside of the fertility clinic setting to interrogate what she names the "ontological choreography" of assisted reproduction and the biomedical mode of reproduction.[33]

Thompson emphasizes the messiness of the clinical experience, including the scheduling of intensive monitoring tests through regular ultrasounds and blood work, the timing of ovulation, the drug regimens, the egg retrieval, and embryo transfer processes. She analyzes the relational work among many parties, including reproductive partners, egg and sperm donors, surrogates, and physicians. Like other feminist theorists of reproductive technologies emerging in the 1990s, she highlights agency through a methodological emphasis on the multiplicity of women's experiences with technologies.

Charis Thompson focuses on "making parents" rather than making babies partly to stress how ARTs since the 1990s have increasingly become accessible to single adults and lesbian and gay couples, that is, those groups for whom it is important to assert "reproductive privacy" in undergoing ARTs and for whom infertility issues are not the primary reason for seeking them out.[34] Similarly, many consumers of second-generation sex-selection technologies avail themselves of ART services as a means to select the sex of their offspring, not because they face infertility. Like single adults and lesbian and gay parents, they may perceive a climate of public disapproval for their reproductive "choices." In her sex-selection guide, for example, Jennifer Thompson writes that she does not reveal her participation in the MicroSort trial while attending an IVF class with other patients, nor does she tell her regular obstetrician to whom she is transferred once her pregnancy via IVF is established.[35]

"Making parents" further suggests a kind of identity politics. Jennifer Thompson, in a description of her "obsession" to have a girl child, writes, "I didn't want to be just a 'boy mom.' "[36] This comment suggests that the flip side of "making particular babies" is the "making of particular parents." In the case of sex selection, new identities may include "girl mom," as in Thompson's case, or family identities such as "complete" or "balanced." The notion that sex selection may have something to do with the identity construction of parents opens up many new questions about the practice that extend far beyond individual "procreative liberty" alone. How is gender constructed relationally within families (both the normative heterosexual family and other types)? How does the sex of children have a bearing upon the gendered identity of parents? Sex-selective choices relate not merely to the embodiment of a desired gender in the resulting child but to the gendered identities and practices of parents/families as well.

Few studies exist on the influence of a child's sex or gender on family process in the United States. In a literature review on this subject, sociologists Sara Raley and Suzanne Bianchi conclude that a son preference exists in the United States in spite of relatively even child sex ratios and presumed gender egalitarianism:

> As a whole, the literature suggests that gender of children has implications for the ways

> in which parents treat, spend time with, invest in, and ultimately receive care from their children later in life. Although some of the evidence is inconclusive, boys, on average, do less housework than girls, have more engaged and perhaps committed fathers, have higher paternal earnings, and have parents with greater marital happiness. In short, boys are more likely than girls to reap the financial and emotional benefits associated with two-parent families.[37]

There is also a dearth of studies on sex preferences of individuals who would use sex-selection technologies. According to one study done by Roberta Steinbacher and Faith Gilroy, birth order may be another factor influencing sex preferences. Of 179 young adults they surveyed who indicated a sex preference for their firstborn child, 72 percent wanted boys.[38]

Although data on child sex preferences in the United States remain scant, the idea that these preferences link in complex ways to parental identity and family processes seems probable.

DOUBLE STANDARDS—SEX SELECTION AND CULTURAL DETERMINISM

New and emerging transnational dimensions of sex selection increasingly defy explanation though feminist theories on cultural difference. The defense of sex selection in the United States has depended on the alterity of sex-selection practices in other nations and cultures, primarily India and China. The social legitimacy of sex selection in the United States is based on the claim that Western societies respect genders equally, lacking any sex- or gender-based discrimination that would negatively influence sex-selection practices. The discursive use of “sex selection” to denote practices in India and China and “gender selection” to denote practices in the United States is one such practice of “othering.” For example, Jennifer Thompson contrasts a brief mention of son preference in “underdeveloped areas” with the U.S. experience: “In the United States . . . there appears to be more interest in trying to conceive a girl—maybe because of American women’s increased roles and rights, their ability to say what they want and to ‘go for it,’ and they often want daughters.”[39] Throughout this personal narrative, Thompson uses “gender” in place of “sex” (for example, gender selection, gender dream, gender determination, gender balance). U.S. popular media and MicroSort recruitment ads also almost exclusively refer to “gender selection” in place of “sex selection,” a word usage that exploits associations of “gender” with empowerment and development.

Professional bioethics discourse has ascribed son preference as the moral basis for condemning sex-selection practices in China and India and “family balancing” as the basis for allowing sex-selection practices in the West. Bernard Dickens et al. invert “the principle of justice that like cases be treated alike” and suggest that similar approaches to sex selection in different settings around the world amount to an ethical injustice. The authors argue that “sex selection for family balancing of subsequent births is not based on cultural discrimination against either sex, and tends to maintain rather than upset a population’s overall birth ratio.” They then argue against son preference as an incentive, which they see as illegitimate, unlike “family balancing.” Prohibitions on sex selection in countries such as Canada, the authors insist, do not serve to eliminate sex discrimination and are “both unjust and oppressive.”[40]

Without denying the importance of cultural specificity, “cultural difference” arguments related to the issue of sex selection assert Western superiority while creating an undifferentiated Other in their representation of Eastern sex-selection practices. They assume the existence of singular and coherent "cultural worlds." "Cultural difference," as maintained by Dickens et al., justifies the use of double standards that exacerbate inequalities between women across cultures. They rule out the possibility of a common alternative ethical basis beyond son preference or family balancing for evaluating sex-selection practices that does not limit our understanding of the technology's meaning to two neatly polarized contexts. Rather than deny the importance of context to understanding sex-selection practices, we need to move beyond simple either/or descriptions that obscure multiscalar (local to global) social, political, economic, and cultural processes at work.

Elisabeth Bumiller's *May You Be the Mother of a Hundred Sons* from the 1980s exemplifies a quintessential Western gaze that condemns Indian practices of sex selection, representing them as primarily culturally determined. During her travels in India she spoke about sex selection with physicians, feminists, and women desiring to abort female fetuses. Invited by one physician to observe a chorionic villus sampling test for sex determination, Bumiller writes:

As I watched the wire's journey on the screen of the ultrasound machine, I slowly became disgusted. It had been building all week, but I think seeing this woman with her legs spread on the examination table, so exposed, and in a sense, so violated by the forces of her society, caused something to snap in me. What right did India have, I thought, to take the newest technology from the West and use it for something as reprehensible as the slaughter of female babies?

Although she recognizes the irony of her own use of "slaughter," given her support of women's abortion rights, she reprimands as "more emotional than rational" Indian feminists who use similar language (as, for example, "female feticide") in their campaigns against sex-selective abortions. Bumiller decides that she cannot reconcile the differences between the United States and India. Like the aforementioned professional bioethicists, she would not ban sex-selective abortions in the United States but finds state regulation to prevent these in India warranted. Likening female infanticide stories from a small, impoverished village in India to accounts of sex-selective abortions in wealthy parts of Mumbai, she blames static Indian culture. "Ultimately," writes Bumiller, "the 'sex test' was proof that education and material progress alone cannot alter traditional attitudes."[41] A number of feminist postcolonial theorists have pointed out similar traps like the one laid here by Bumiller that condemn, in this case, "Indian culture" for sexist practices at the same time as they exonerate Western practices from criticisms related to culture.

Bumiller's argument resembles the "death by culture" rhetoric of "othering" that Uma Narayan illuminates in her analysis of contrasting perceptions of dowry murders in India and domestic violence murders in the United States. Similarly, Nira Yuval-Davis underlines that "essentialized constructions of 'cultural difference' constitute one of the major modes of contemporary popular racisms." Cultural difference gets marked through discursive objects such as "Third World Women," which can assist the boundary construction of sex-selection practices along "cultural world" lines. Chandra Mohanty has contrasted portrayals of Western women in scholarship "as educated, as modern, as having control over their own bodies and sexualities, and the freedom to make their own decisions" with that of the Third World woman as "an essentially truncated life based on her feminine gender (read: sexually constrained) and her being 'third world' (read: ignorant, poor, uneducated, tradition-bound, family-orientated, victimized)."[42] The construct, "Third World women," then, flexibly fits notions of "bad" sex-selection practices in faraway cultures, whether that Third World woman is viewed as an ignorant perpetrator or as oppressed victim of violence against women. Similar to (mis)understandings of other issues of violence against women in India represented across borders, sex selection has become strongly decontextualized in the U.S. popular imagination. Media, professional bioethics, and some academic discourses in the United States reinforce simplistic cultural explanations for what has gone wrong with sex selection in the East.

Applying a singular standard to evaluate sex selection in countries of Asia obscures the varied factors that drive sex-selection practices in those regions beyond son preference alone. For example, sex selection is often practiced among the Indian middle and upper classes, which desire smaller families and face neoliberal consumerist pressures. Rupsa Mallik adds to son preference a host of other factors that drive sex-selective abortions in India, such as state population policies that impose a two-child norm; prosperity in states such as Punjab and Haryana, which as a result of rapid upward mobility have seen a decrease in female labor participation and an increase in dowry payments; and even high levels of female education, combined with access to information and technology in Delhi and Chandigarh, which Mallik argues have led to greater autonomy among women seeking sex selection. Jennifer Thompson generalizes discriminatory forms of sex selection as all stemming from "underdeveloped areas," but Mallik provides an alternative understanding that implicates the very forces of "development" in India's rising sex-selective abortions:

> Modernization, defined as increased access to education and communication technology, has also contributed in the diffusion of SD [sex determination] and SSA [sex-selective abortion]. This is notable in the role that mass media plays in the spread of upper caste values and the accompanying anti-female bias. Adoption of these norms by communities that have traditionally been more egalitarian towards women has also served to intensify discrimination against women.[43]

Mallik's insight troubles depictions proffered by Jennifer Thompson and Bumiller that underdetermine individual agency just as they overdetermine notions of ahistorical cultural forces in defining Eastern sex-selection practices. Just as we cannot deny that individuals in India may seek sons in an effort to balance their families, we cannot overlook that sex preferences in the United States may be tied to larger familial and cultural pressures. On the other hand, media accounts in the United States portray science (not culture) as compelling Western sex-selection practices undertaken by technologically enabled, autonomous individuals.

Emerging U.S. sex selection calls for new feminist analysis that can dislodge widely held assumptions about agency, access, and constraints related to technology use, which are bound to particular geopolitical contexts. For example, India too has become a site where transnational consumers (not to mention its own growing middle class) can access state-of-the-art ARTs relatively inexpensively. Shree Mulay and Emily Gibson, in their research on Indian marketing of assisted reproductive services to foreigners, uncover evidence of this trend, including a marked rise in Web sites soliciting medical tourism (these sites quadrupled in just two years, from 2004 to 2006); the advent of the twelve-month "medical visa" (unlike the six-month tourist visa); presence of a strong private sector with "up-market tertiary hospitals"; and state, federal, and international (World Trade Organization) economic policies that promote medical tourism.[44]

Second-generation sex-selection technologies and a burgeoning market for assisted reproduction services led the Indian government to expand its regulation of prenatal diagnostic technologies to include prepregnancy sex selection. Yet imperialist "othering" perceptions obscure an understanding of high-tech prepregnancy methods in India as well as use of sex-selective abortion in the United States.

The practices of "othering" sex selection also obscure the fact that cultural differences rarely coincide neatly with geopolitical boundaries. The targeted marketing of sex selection to U.S.-based immigrant communities with known son preference[45] and the phenomenon of "reproductive tourism" to the United States by persons who wish to bypass regulatory restrictions to these technologies in their own countries provide evidence to the contrary. For example, National Public Radio (NPR) reported on December 20, 2006, that 90 percent of foreign-born patients from Korea, India, or China who access the Huntington Reproductive Center in Southern California for sex selection ask for a boy. Moreover, the NPR report interviewed an Indian-born couple now residing in British Columbia, Canada. After having two girls conceived naturally, the couple traveled to California to access PGD for selecting a male embryo.[46]

Political-economic factors that implicate the United States in India's rising sex-selective abortions debunk the widespread perception of sex-selection problems there as solely culturally determined. The U.S. company, General Electric (GE), for example, captured the largest market share for ultrasound scanners in India. GE sold a disproportionate number of these machines in northwest India, where the female-to-male child sex ratio is now among the lowest in the country.[47] In an effort to enforce implementation of the 1994 act that banned sex selection, the Indian Supreme Court in 2001 ordered, among other measures, that companies such as Wipro GE, Philips Medical Systems, and Siemens provide information on the individuals or groups to whom they sold ultrasound machines in the previous five years. Another American company, Gen-Select, recently marketed dubious sex-selection kits in the *Times of India*.[48]

Furthermore, the United States has a long history of supporting population control measures in India, and some proponents of sex selection view it as an ideal form of family planning and population control. The U.S. Agency for International Development (USAID) has influenced the formation of population policies that promote a two-child norm in states such as Uttar Pradesh and Andhra Pradesh. These have led to intensification in sex-selection use. USAID has notably remained silent on the issue of increased sex-selection practices in India.[49]

Although the defense of "gender" selection in the United States has depended on contrasting and flattening perceptions of "sex" selection in India, the political and economic factors affecting sex selection often occur transnationally, as do practices of sex selection, The factors that drive sex selection practices around the world are increasingly complex, defying explanation through cultural or economic difference alone. They necessitate moving away from double standards in evaluating the social and ethical implications of these technologies. We need broader frames that can encompass all of the messiness and contradictions associated with transnational sex-selection practices. In the next section, I explore one possible alternative framework that stems from new feminist theorizations in the sociology of health and illness.

TOWARD AN ALTERNATIVE FRAMEWORK: SEX SELECTION AS A CASE STUDY OF BIOMEDICALIZATION

To suggest a potentially productive, theoretical site for analyzing sex selection, I draw on theories of "biomedicalization" by feminist sociologists Adele E. Clarke, Janet K. Shim, Laura Mamo, Jennifer Ruth Fosket, and Jennifer R. Fishman. Clarke et al. illuminate five politico-economic, technoscientific, and sociocultural processes that together constitute biomedicalization, expanding on Irving Zola's approach to medicine as an institution of social control. According to Clarke and her coauthors, medicalization refers to "the extension of medical jurisdiction, authority, and practices into increasingly broader areas of people's lives." Medicalization is the process by which previously social issues come under the medical gaze. The authors claim that technoscientific innovations in biomedicine since around 1985 have led to "a second 'transformation' of American medicine" revealed through new social forms and major changes in the organization and practices of contemporary medicine.

In the current technoscientific revolution, "big science" and "big technology" can sit on your desk, in a pillbox, and inside your body. That is, the shift to biomedicalization is from enhanced control over external nature (i.e., the world around us) to the harnessing and transformation of internal nature (i.e., biological process of human and nonhuman life forms), often transforming "life itself."[50]

"From the inside out" is a repeated metaphor in the paper on biomedicalization, which captures the basic idea of "harnessing and transformation of internal nature." I have borrowed it here to highlight how new forms of sex selection represent a social and cultural construction of gender from within bodies.

Central to the definition of biomedicalization is a notion of power far more flexible, contingent, and less essentialized than in former social critiques of biomedicine. Given the privileged social locations of patients/consumers of sex selection in the United States, who do not readily fit the model of a socially controlled group imposed upon by an all-powerful medical establishment, I find this framework particularly useful in analyzing second-generation sex-selection practices. Clarke et al. define biomedicalization as "the increasingly complex, multisited, multidirectional processes of medicalization, both extended and reconstituted through the new social forms of highly technoscientific biomedicine."[51] I argue that sex selection constitutes a case study of biomedicalization. I briefly return to some points made in prior sections to highlight how they pertain to biomedicalization processes.

PGD and MicroSort were developed in a new era of medical science and technology that increasingly focuses on genes, proteins, and genomes. They represent a trend that some scholars call "geneticization," which refers to the study of differences in humans at chromosomal and DNA levels. Clarke et al. refer to the merging of geneticization with computer and information technology as the technoscientization of biomedicine. In PGD, social differences in human gender are constructed at the level of chromosomes extracted from day-old embryos.

The development and spread of new knowledges on second-generation sex-selection technologies by consumers via the Internet and popular media represent the changing faces of information production and distribution indicative of biomedicalization. No longer does medical knowledge simply emanate from scientific literature and medical professionals. Popular media, Internet support forums, and other literature stemming from nonmedical professionals, along with medical discourses, have paved the way for the growing social legitimacy of sex selection. Concurrent with the rise of second-generation sex-selection technologies came advancements in information technology and its rapid accessibility across national boundaries. By serving as the foundation for the development of chat rooms and medical tourism enterprises, information technology propelled the transnationalization of sex selection.

One outcome of a gene age beginning in the 1990s is that genetics (and a kind of genetic determinism) has attained cultural primacy over environmental, social, cultural, political, and economic determinants of human subjectivity. The construction of identity through technoscientific means represents another process that signals biomedicalization. Clarke et al. explain that "biomedicalization enacts its regulation of bodies through offering not just 'control over' one's body through medical intervention (such as contraception) but also 'transformation of' one's body, selves, health" that can create "new selves and identities (mother, father, walker, hearer, beautiful, sexually potent person)."[52] As discussed above, consumers of sex selection often seek new individual ("girl mom") or family ("balanced") identities. In this way, sex selection represents a customization of children's sex to fit individual adult preferences and to create technoscientifically based parental or family identity.

In a discussion on the economics of biomedicalization, Clarke et al. stress the growing privatization and corporatization of medical research and practice as well as other globalization trends. They coin the term "Biomedical TechnoService Complex, Inc." to describe the current manifestations of a medical industrial complex in order to stress the multinational and globalizing "*corporatized* and *privatized* (rather than state-funded) research, products and services made possible by technoscientific innovations that further biomedicalization."[53] These developments ring especially true for assisted reproduction industries. Research on PGD, for example, has taken place without the oversight of U.S. federal regulatory and data collection authorities.[54]

Recent developments in sex selection precipitated by the advent of second-generation technologies require a broader framework of analysis in order to accommodate the multiplicity of social, cultural, economic, political, and ethical implications. Biomedicalization describes many new transformations since 1985 that mark the confluence of medicine and the larger U.S. society. Conversely, the applicability of these processes to sex selection may help validate the emerging concept of biomedicalization itself.

Since the late 1990s several factors have led to an increased acceptance of sex selection in the United States, including the development of new marketable forms of prepregnancy technologies that do not require an abortion. Receiving much attention in popular media, these methods have also been publicized through Internet consumer activist and support sites for those who desire to select the sex of their children. In spite of these trends, the issue of sex selection remains undertheorized among U.S. feminists. In the past, the reluctance to engage the issue of sex selection came about because of its close association with abortion and because it was viewed as irrelevant to U.S. concerns and contexts. I argue that now it is time for U.S. feminists to investigate and weigh in on this issue. We should not allow medical, bioethical, and popular discourses, which currently present a simplistic "West is best" picture, to monopolize this discussion. Instead, we should realize that in comparison to other postindustrial countries such as the United Kingdom and Canada, regulation of sex selection marketing and practices in the United States is inadequate. Minimally, U.S. feminists should demand that fertility clinics adhere to ASRM ethical guidelines that discourage the use of PGD for nonmedical sex selection and stop advertising sex-selection services. They should also question the promotion of "family balancing" as an ideal.

The increasing availability of U.S.-based sex-selection practices comes with high stakes. These include the very meaning of reproductive rights, the deployment of sex and gender binaries, and the application of double standards in the way sex-selection practices are evaluated transnationally. In this article, I have argued that feminist sociologists who view U.S. sex-selection practices in the frame of biomedicalization may provide a more varied and complex picture of the dimensions of power and difference effaced by libertarian views on sex selection. Sex selection has the potential to complicate notions of stratified reproduction and undo singular notions of stratified reproductive identity (whether valued or despised). Viewing sex selection as a transcultural issue helps us to move beyond long-standing binary ways of thinking about reproductive technology across global divides. We need a more complex picture of reproductive stratification that does not pigeonhole particular categories of women into particular strata, associating sex-selective abortion exclusively with population subjects in the global South and "gender preselection" with individual subjects in the United States. In an age of globalization and medical tourism, it is clear that U.S. feminisms must engage sex selection in a way that accounts for the multiple and varied social, cultural, and medical worlds that increasingly overlap, here and abroad. In this way, U.S. feminists have something to gain from an incorporation of sex selection into our understandings of reproductive politics, long centered here on the issue of abortion. Attention to this issue may help build solidarities for a renewed transnational feminist politics of reproduction.

NOTES

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CHAPTER 19

Race, Gender, and Genetic Technologies: A New Reproductive Dystopia?

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In the 1980s, Margaret Atwood, Gena Corea, and other feminists imagined dystopias in which white women's reproduction was valued and privileged and the reproduction of women of color was devalued and exploited. In *The Handmaid's Tale,* published in 1985, Atwood envisioned the repressive Republic of Gilead, where handmaids were forced to serve as breeders for elite men and their infertile wives in order to perpetuate the white race, while blacks, as well as handmaids who failed to bear children, were exiled to toxic colonies (Atwood 1985). That same year, in *The Mother Machine,* Corea predicted that white women would hire surrogates of color in reproductive brothels to be implanted with their eggs and gestate their babies at low cost (Corea 1985).

Two decades later, feminist scholars have continued to critique the hierarchy that anthropologist Rayna Rapp aptly calls "stratified reproduction" by contrasting the opposing relationships of white women and women of color to reproduction-assisting technologies (1999, 310). At the turn of the twenty-first century, even more advanced reproductive technologies that combine assisted conception with genetic selection, or reprogenetics, threaten to intensify this opposition (Roberts 2005; Parens and Knowles 2007). With preimplantation genetic diagnosis (PGD), clinicians can biopsy a single cell from early embryos, diagnose it for the chance of having hundreds of genetic conditions, and select for implantation only those embryos at low risk of having these conditions (Robertson 2003; Spar 2006; Singer 2007). As Reprogenetics, a New Jersey genetics laboratory that specializes in PGD, puts it, this technique allows for the "replacement to the patient of those embryos classified by genetic diagnosis as normal."[1]

At a time when wealthy white women have access to technologies that assist them in having children who not only are genetically related to them or their partners but have also been genetically screened, various laws and policies discourage women of color from having children at all (Roberts 1998; Smith 2007). As Rapp stated at a Radcliffe Institute conference, Reproductive Health in the Twenty-first Century, in October 2004, "Some women struggle for basic reproductive technologies, like a clinic where sterile conditions might be available to perform C-sections, while others turn to cutting-edge genetic techniques" (quoted in Drexler 2005). African American studies scholar Marsha Darling similarly writes, "This stunning array of biotechnology is being directed at developing eugenical population control strategies especially for low-income and poor women of color globally," while "reproduction enhancement options under the rubric of 'choice' " are reserved "for economically and racially privileged women in the global North" (2004b).

While welfare reform laws aim to deter women receiving public assistance from having even one additional healthy baby (Mink 2002; Smith 2007), largely unregulated fertility clinics (Arons 2007, 1; Parens and Knowles 2007) regularly implant privileged women with multiple embryos, knowing the high risk multiple births pose for premature delivery and low birth weight (Helmerhorst et al. 2004; Mundy 2007; Reddy et al. 2007). The public begrudges poor mothers a meager increase in benefits for one more child, but it celebrates the birth of high-tech septuplets that require a fortune in publicly supported hospital care (Andrews 1999, 55–61). The multibillion-dollar apparatus devoted to technologically facilitating affluent couples' procreative decisions stands in glaring contrast to the high rate of infant death among black people, which remains more than twice the rate for whites (Mathews and MacDorman 2007). Indeed, the infant mortality rate is climbing in Mississippi and other southern states (Eckholm 2007).

My prior writing on this reproductive caste system also contrasted policies that penalize poor black women's childbearing with the high-tech fertility industry that promotes childbearing by more affluent white women (Roberts 1998, 246–93). I recently reconsidered the positioning of white women and women of color in the reproductive hierarchy, however (Roberts 2005). Rather than place these women in opposition, I tied them together in relation to the neoliberal trend toward privatization and punitive governance. Both population control programs and genetic selection technologies reinforce biological explanations for social problems and place reproductive responsibility on women, thus privatizing remedies for illness and social inequity.

Population control ideology attributes social inequities to childbearing by poor women of color, thereby legitimizing punitive regulation of these women's reproductive decisions (Roberts 1998). Stereotypes of black female sexual and reproductive irresponsibility support welfare reform and law enforcement policies that severely regulate poor black women's sexual and childbearing decisions (Neubeck 2001). By identifying procreation as the cause of deplorable social conditions, reproductive punishments divert attention away from state responsibility and the need for social change. Black mothers' crack use, for example, became a primary explanation for high rates of black infant mortality, although this disparity long predated the crack epidemic (Roberts 1998, 154–59; Zerai and Banks 2002; McCaughey 2005).

Like punishments for poor women's childbearing, reprogenetics also shifts responsibility for promoting well-being from the government to the individual by making women responsible for ensuring the genetic fitness of their children. The individual woman becomes the site of governance through self-regulation of genetic risk (Mykitiuk 2000). The medical model of disability that promotes eugenic elimination of genetic risk instead of ending discrimination against disabled people supports state reliance on individuals to secure their own well-being through the use of genetic technologies. This diversion of attention away from social causes and solutions reinforces privatization, the hallmark of a neoliberal state that seeks to reduce social welfare programs while promoting the free market conditions conducive to capital accumulation. Thus, reproductive health policies involving women at opposite ends of the reproductive hierarchy play an important role in the neoliberal state's transfer of services from the welfare state to the private realm of family and market.

In the last several years, while working on a book project exploring the growth of biotechnologies that incorporate race as a genetic category, I have come to reconsider once again the opposition of white women and women of color in the reproductive caste system in relation to reproductive technologies. The position I just described, like the 1980s reproductive dystopias, still casts white women as the only consumers of reproductive technologies and women of color only as victims of population control policies. It assumes that white women are the only ones with access to these technologies and that women of color play no part in the politics of reprogenetics, except by their exclusion or exploitation.

The recent expansion of both reproductive genetic screening and race-based biomedicine, however, signals a dramatic change in the racial politics of reproductive technologies. First, the important role of genetic screening, which makes individual citizens responsible for ensuring good health by reducing genetic risk, may support the wider incorporation of reprogenetic technologies into the neoliberal health care system. Second, companies that market race-based biotechnologies now promise to extend the benefits of genetic research to people of color (Bloche 2004; Kahn 2007). Media promoting genetic technologies prominently feature people of color in images representing the new genetic age, in contrast to prior portrayals that emphasized whiteness as the exclusive standard of genetic fitness.[2] Moreover, some clinics that offer high-tech reproductive services, including PGD, explicitly appeal to clients of color.[3] Women of color are now part of the market and cultural imaginary of the new reprogenetics. We need a new reproductive dystopia that accounts for the changing racial politics of genetics and reproduction.

In this article, I critically explore the role of race and racism in the emergence of reproductive technologies that incorporate advances in genetic science. What are the implications of including women of color in the market for reprogenetic technologies, particularly when this is done with the expectation that women will use these technologies to manage genetic risk? In investigating this question, I hope to shed light on the critical relationship between racism, neoliberalism, and reproduction.

EXPANDING THE MARKET FOR REPRODUCTIVE TECHNOLOGIES

In *Killing the Black Body,* I discussed the role of race in images promoting the fertility industry (Roberts 1998, 251). I pointed out that pictures showing the success of reproduction-assisting technologies were always of white babies, usually with blond hair and blue eyes, as if to highlight their racial purity. When the *New York Times* launched a prominent four-article series called “The Fertility Market” in January 1996, for example, the front page displayed a photograph of the director of a fertility clinic surrounded by seven white children conceived there (Gabriel 1996, A1). The continuing page contained a picture of a set of beaming in vitro fertilization (IVF) triplets, also white (Gabriel 1996, A18).

In the 1990s, the only time black babies figured in media coverage of these technologies was in stories intended to evoke revulsion precisely because of their race. One instance was a highly publicized lawsuit brought by a white woman against a fertility clinic she claimed had mistakenly inseminated her with a black man’s sperm, resulting in the birth of a mixed-race child (Schatz 1990; Sullivan 1990). Two reporters covering the story speculated that “if the suit goes to trial, a jury could be faced with the difficult task of deciding damages involved in raising an interracial child”

(Kantrowitz and Kaplan 1990). The perceived harm to the mother of receiving the wrong sperm was intensified by the clinic's failure to deliver a white baby.

Other notorious news stories from the 1990s included the case of twin boys born to a white Dutch couple who discovered when the babies were two months old that one was white and one was black (Elliot and Endt 1995). The fertility clinic had fertilized the mother's eggs with sperm from both her white husband and a black man. A landmark California dispute from 1993, *Johnson v. Calvert,* involved a black gestational "surrogate," Anna Johnson, who was denied any rights to the child she bore for the genetic parents, a white man and his Filipina wife, Mark and Crispina Calvert.[4] The press paid far more attention to Anna Johnson's race than to that of Crispina Calvert. It also portrayed the baby as white. By relying on the Calverts' genetic tie to the child to determine legal parenthood, the California courts ensured that a black woman would not be considered the natural mother of a white child (Roberts 1998, 280–81). While the stories involving whites portrayed the positive potential of new reproductive technologies, the stories involving women and children of color revealed their potential horror.

Today, however, the high-tech fertility business, including genetic-screening services, no longer appeals to an exclusively white clientele. Although fertility clinics perform sex selection for a range of clients, the controversy surrounding this service has centered on Chinese and Indian women (Darnovsky 2004; Bumgarner 2007). Images on fertility clinic Web sites routinely show people of color alongside claims advertising clinic services and their benefits. To be sure, pictures of white babies continue to dominate some Web sites. The home page of the Rinehart Center for Reproductive Medicine in Illinois displays the head of a blond-haired baby emerging like the sun from billowing white clouds to illustrate its promise of "turning your dreams of starting a family into reality."[5] Sher Institutes for Reproductive Medicine, with nationwide locations, streams photo strips of its "success stories," showing dozens of children, all of whom appear to be white.[6]

Similarly, a full-page advertisement for the Virginia-based Genetics and IVF Institute, which recently appeared in the *New York Times Magazine,* features a giant photo (taking up about half the space) of a white baby with blonde hair, blue eyes, and rosy cheeks.[7] The headline asks, "Over 40 and thinking of having a baby?" followed by the solution: "DONOR EGG Immediate Availability." In the text below, the company boasts of offering "Doctoral Donors with advanced degrees and numerous other donors with special accomplishments and talents." The assumption that whiteness, intelligence, and talent are connected and hereditary remains robust in the reprogenetic marketplace.

Nevertheless, the images associated with reproductive technologies have dramatically diversified in recent years. Reproductive Health Specialists in Illinois displays a photograph of a large group of white couples holding white babies, captioned "Baby Picnic."[8] But its Web site also contains a photograph of a smiling black man and woman and a drawing of a pregnant black woman attended to by a black male partner and female physician. Likewise, Houston IVF's Web site shows a beaming black couple holding a black baby.[9] The Illinois-based Karande and Associates takes a very multicultural approach, using a photo of a pregnant East Asian woman for scheduling an appointment, a black woman and child for its link to donor egg information, and a South Asian man and child for the insurance information link.[10]

There are numerous advertisements on craigslist.com explicitly soliciting egg donors of color. For example, a posting by

Beverly Hills Egg Donation notes, "ALL ETHNICITIES WELCOME!"[11] F. Williams Donor Services' listing states, "Ethnic Diverse Egg Donors Needed" and includes a photo of an Asian, a white, and a black woman.[12] Happy Beginnings, LLC, advertises, "EGG DONORS WANTED ALL ETHNIC BACKGROUNDS," specifying, "WE HAVE A VERY HIGH DEMAND FOR JEWISH, EAST INDIAN, MIDDLE EASTERN, ASIAN, ITALIAN, AND BLONDE DONORS."[13] Similarly, Pacific Fertility Center boasts that it "maintains a diverse egg donor database including Jewish egg donors, Asian egg donors, and a variety of backgrounds and ethnicities."[14]

Some fertility clinic Web sites not only market their reprogenetic services to people of color, but they also perform race-based genetic testing as part of those services. Pacific Fertility Center's Web site includes the statement, "Genetic screening is also recommended, based on ethnic background."[15]

Reproductive Genetics Institute in Chicago similarly includes race in the factors it takes into account in its genetic testing: "Screening Results and Accuracy: By combining the results of the ultrasound and blood test along with the age, race and weight of the mother, a number can be generated by computer which represents the risk of the pregnancy being affected by Down syndrome or another chromosome problem. Experience has shown that, together, the ultrasound and blood screen will identify approximately 90% of babies with chromosome abnormalities."[16]

Fertility clinics' use of race in genetic selection procedures may help to reinforce the erroneous belief that race is a biological classification that can be determined genetically or that genetic traits occur in human beings according to their race. Social scientists' demonstration that race is an invented social grouping was confirmed by genomic studies of human variation, including the Human Genome Project, showing high levels of genetic similarity among people of all races (Graves 2001; Cooper, Kaufman, and Ward 2003). At the onset of the Human Genome Project, some scholars believed that the science of human genetic diversity would replace race as the preeminent means of grouping people for scientific purposes (Lewontin 1995; Reardon 2005). Yet the use of race as a biological category in genetic research and biotechnology is intensifying (Burchard et al. 2003; Bonham, Warshauer-Baker, and Collins 2005; Duster 2005).

The marketing of high-tech reproductive services to women of color is part of a broader inclusion of minority groups in the testing and production of cutting-edge biotechnologies. In June 2005, the Food and Drug Administration (FDA) approved the first race-based pharmaceutical, BiDil, to treat heart failure specifically in African American patients (Saul 2005). BiDil is the combination of two generic drugs that doctors were already prescribing regardless of race. Yet the FDA permitted its maker, Nitromed, to market BiDil as a drug for black people. Making BiDil race specific also allowed Nitromed to extend its patent to the year 2020, giving the company market exclusivity and the potential to reap huge profits on drug sales (Kahn 2004). The manufacturer's unproven theory supporting the need for a race-specific therapy is that the reason for higher mortality rates among black heart patients lies in genetic differences among "races," in either the reason for getting heart disease or the reason for responding differently to medications for it (Kahn 2004; Sankar and Kahn 2005).

BiDil is only one example of the growing trend toward "the strategic use of race as a genetic category to obtain patent protection and drug approval" (Kahn 2006, 1349). In his survey of gene-related patent applications, legal scholar Jonathan Kahn discovered that the use of race has increased fivefold in the past twenty years (2006). Claims about justice in scientific research have shifted away from protecting socially disadvantaged subjects from unethical practices and toward promoting access to clinical trials and biotech products (Epstein 2007). There is strong support for racial therapeutics among some black advocates, researchers, and physicians precisely to redress past discrimination and fulfill long-standing demands for science to attend to the health needs of African Americans (Puckrein 2006; see Roberts 2008). This increased commercial and popular demand for race-specific pharmaceuticals threatens to reinforce a false belief in the biological origin of race.

Advanced reproductive technologies similarly constitute a form of race-based medicine. Rather than serve an exclusively white clientele, fertility clinics are marketing genetic technologies to women of color on the basis of race and ethnicity and incorporating race in genetic-screening procedures. Contemporary reproductive dystopias, then, should not categorically exclude women of color from their imagined users of genetic selection technologies. As I explain below, the expansion of race-based biotechnology, including genetic selection, fits within the neoliberal trend toward privatization and punitive governance and requires adjusting feminist reproductive dystopias.

NEOLIBERALISM AND REPRODUCTIVE DYSTOPIA

The marketing of reprogenetics to women of color is taking place in the context of neoliberal shifts in governance that may encourage the expansion of genetic-screening technologies to a broader clientele. Widespread prenatal testing has already generated greater surveillance of pregnant women and assigned them primary responsibility for making the "right" genetic decisions. It is increasingly routine for pregnant women to get prenatal diagnoses for certain genetic conditions such as Down syndrome or dwarfism (Powell 2007; Saxton 2007). It is also often expected that they will opt for abortion to select against any disabling traits identified by genetic testing. Many obstetricians provide these tests without much explanation or deliberation because they consider such screenings to be a normal part of treating their pregnant patients. The director of reproductive genetics at a large Detroit hospital reported that at least half of the women referred there with an abnormal amniocentesis result were "uncertain about why they even had the test" (Consumers Union 1990, 486). Moreover, current tort case law creates incentives in favor of genetic testing by imposing legal duties on obstetricians to offer it (Weil 2006, 52; Ossorio 2007, 330). While there are virtually no legal consequences for doctors who encourage genetic tests, doctors who fail to use them may be liable for damages in "wrongful birth" lawsuits.[17]

Although genetic counseling should be nondirective, many counselors show disapproval when patients decide against selective abortion. A genetic counselor asked a woman who decided to bear a child with Down syndrome, "What are you going to say to people when they ask you how you could bring a child like this into the world?" (quoted in Helm, Miranda, and Chedd 1998, 59). Brian Skotko's survey of 985 mothers who received postnatal diagnoses of Down syndrome for their children similarly discovered that many of the mothers were chastised by health care professionals for not undergoing prenatal testing:

> "Right after [my child] was born, the doctor flat out told my husband that this could have been prevented or discontinued at an earlier stage of the pregnancy," wrote one mother who had a child with DS in 2000. A mother who had a child in 1993 recalled, "I had a resident in the recovery room when I learned that my daughter had DS. When I started to

> cry, I overheard him say, 'What did she expect? She refused prenatal testing.'" . . . Another mother reported, from her experience in 1997, "The attending neonatologist, rather than extending some form of compassion, lambasted us for our ignorance in not doing prior testing and for bringing this burden to society—noting the economical, educational, and social hardships he would bring." Regarding a postnatal visit, a mother who had a child in 1992 wrote, "[My doctor] stressed 'next time' the need for amniocentesis so that I could 'choose to terminate.'" (2005, 70–71)

As a result of such pressure, many pregnant women now view genetic testing as a requirement of responsible mothering (Harmon 2007).

Poor women, especially women of color, currently face financial and other barriers to receiving high-tech infertility services (Elster 2005). Because genetic screening is now considered an essential part of preventive medicine, however, these technologies are becoming integrated into social welfare systems and private insurance schemes and are likely to become increasingly available to poor and low-income women (Van den Daele 2006; Bumiller 2009).[18] Unlike IVF, whose primary purpose is to increase fertility, PGD functions to help women avoid starting a pregnancy that entails disfavored genetic traits (Franklin and Roberts 2006, xx, 97).[19]

The aim of IVF is to produce the birth of a live baby; the aim of PGD and fetal diagnosis is to prevent the birth of certain children. While government welfare systems have disdained facilitating childbearing by poor women of color by declining to fund fertility treatments, they may therefore treat genetic testing differently.

The current ban on federal funding of abortion places a significant limit on state genetic selection programs (Powell 2007, 49–50). In states that do not provide Medicaid funding for abortion, poor women can receive state-sponsored genetic testing but have to pay for the cost of selective abortions themselves. Yet it is not hard to foresee future federal and state legislation that exempts "therapeutic" abortions based on genetic testing from the ban on abortion funding. Prior to the 1973 passage of *Roe v. Wade,* upholding the constitutional right to abortion, many states permitted therapeutic abortions recommended by physicians while criminalizing elective abortions sought by women with unwanted pregnancies (Schoen 2005, 153–86).

Indeed, some clients of reprogenetics have claimed moral superiority over women who have had abortions for nonselective reasons. In a July 22, 2004, op-ed piece in the *New York Times,* Barbara Ehrenreich calls on women who had aborted fetuses based on prenatal diagnosis to support the general right to abortion (2004). She notes that these women sometimes distinguish themselves from women who have "ordinary" abortions. One woman who aborted a fetus with Down syndrome states, "I don't look at it as though I had an abortion, even though that is technically what it is. There's a difference. I wanted this baby" (quoted in Ehrenreich 2004, A21). On a Web site for a support group called "A Heart breaking Choice" a mother who went to an abortion clinic complains, "I resented the fact that I had to be there with all these girls that did not want their babies" (quoted in Ehrenreich 2004, A21). The incorporation of eugenic values in arguments for women's reproductive freedom neglects the history of abortion regulation, which limited women's reproductive freedom by distinguishing between approved therapeutic and disapproved elective abortions. An attempt to solicit supporters of selective abortion to join the cause of abortion rights misunderstands the nature of reproductive politics in the neoliberal age.

The expansion of genetic research and technologies has helped to create a new biological citizenship that enlists patients to take unprecedented authority over their health at the molecular level (Rose 2007). According to British sociologist Nikolas Rose, "our very biological life itself has entered the domain of decision and choice" (2007, 40). Some scholars have highlighted the enhancement of human agency, as "patients are increasingly urged to become active and responsible consumers of medical services and products ranging from pharmaceuticals to reproductive technologies and genetic tests" (2007, 4) and to form alliances with physicians, scientists, and clinicians to advocate for their interests (Franklin and Roberts 2006, xvii).

Biological citizenship also reflects the shift of responsibility for public welfare from the state to the private realms of market and family. As Rose observes, responsibility for the management of health and reproduction has devolved from the "formal apparatus of the government" to "quasi-autonomous regulatory bodies" such as bioethics commissions, professional groups, and private corporations (2007, 3). Selling genetic testing products directly to consumers is big business for private fertility clinics and biotechnology companies. Biomedical research and technology have correspondingly become major sources of capital accumulation, aided by federal patents on genetic information, FDA approval of pharmaceuticals, and public funding of lucrative private research ventures, such as California's stem cell research initiative.

In this neoliberal context, genetic testing serves as a form of privatization that makes the individual the site of governance through the self-regulation of genetic risk (Mykitiuk 2000). Reproductive genetic technologies, in particular, introduce a new gendered division of labor and surveillance as women bear the brunt of reprogenetics' contribution to the neoliberal restructuring of health care (Mykitiuk 2000). Canadian legal scholar Roxanne Mykitiuk points out that, contrary to the deregulation that typically occurs in the service of big business, the new duties imposed on women constitute a reregulation that supports capital investment in market-based approaches to health care and other social needs while state investment in public resources shrinks (2000).

In addition, reprogenetics incorporates a seemingly benign form of eugenic thinking in its reliance on reproductive strategies to eliminate genetic risk rather than social strategies to eliminate systemic inequities. Some disability rights advocates oppose prenatal genetic diagnosis that leads to discarding embryos and fetuses predicted to have disabilities because these procedures devalue people who have disabilities, sending the message that they should never have been born (Wendell 1996, 151–56; Parens and Asch 2007; Saxton 2007). They argue that although disabilities cause various degrees of impairment, the main difficulty in having a disability stems from pervasive discrimination. "Rather than improving the medical or social situation of today's and tomorrow's disabled citizens," write bioethicists Erik Parens and Adrienne Asch, "prenatal diagnosis reinforces the medical model that disability itself, not societal discrimination against people with disabilities, is the problem to be solved" (2007, 13).

The reasons why some parents do not want a disabled child are varied. While some women may use genetic selection in an upwardly mobile quest for the "perfect child," others want to prevent their children from suffering the pain, illness, and physical limitations that accompany disabilities or worry that they are not capable of dealing with disability's social consequences (Wendell 1996, 82–83; Franklin and Roberts 2006, 132–62; Baily 2007). Yet given medical professionals' implicit directive favoring genetic selection and powerful stereotypes that negatively depict disabled people, many women are left with a false impression of the nature of parenting a disabled child and the quality of disabled people's lives (which genetic testing cannot predict; Bumiller 2009). Pregnant women are rarely able to make truly informed decisions about what to do with test results because they, obstetricians, and counselors typically have little information about the lives of disabled people and their families (Wendell 1996, 81–84; Parens and Asch 2007, 33–37).[20]

Moreover, some of the undesirable events likely to happen to a child with a serious disability that parents may reasonably wish to prevent, such as limited educational and employment opportunities, are caused by social as much as physical impediments (Steinbock 2007, 119). Unable to count on societal acceptance or support, many women feel compelled to turn to genetic testing to ensure their children's welfare (Lippman 1991, 39; Kittay 2007, 181). Without judging the morality of individual women's decisions, we must critically evaluate the social, political, and legal incentives for genetic testing as well as consequences of genetic testing for people with disabilities. Building on the disability critique, we must also question the role that the eugenic approach to disability plays in neoliberal governance.

Rose, the British sociologist discussed above, rejects critical intellectuals' use of eugenics rhetoric to contest PGD and other aspects of contemporary biological politics (2007, 54–68). He argues that the eugenics practiced in the first half of the twentieth century was a particular biopolitical strategy that sought to improve the population as a whole through deliberate state action. This effort "to control the biological makeup of the population" as a whole, he claims, distinguishes eugenics from the new biopolitics' concern with the genetic health of individuals (2007, 56). "What we have here, then, is not eugenics but is shaped by forms of self-government imposed by obligations of choice, the desire for self-fulfillment, and the wish of parents for the best lives for their children," Rose concludes (2007, 69).

Rose dismisses the relevance of eugenics to contemporary biopolitics too categorically. He downplays critical aspects of the past eugenics regime that characterize both contemporary population control policies and genetic-screening technologies such as PGD. By eugenic thinking or values, I refer to the belief that reproductive strategies can improve society by reducing the births of socially marginalized people. The eugenic approach to social problems locates them in reproduction rather than social structure and therefore seeks to solve them by eliminating disfavored people instead of social inequities. Its chief epistemological device is to make the social order seem natural by casting its features as biological facts. As Donald MacKenzie observes, eugenic theory is "a way of reading the structure of social classes onto nature" (1981, 18). Programs based on such a belief set up standards for reproduction that subsume childbearing under prevailing hierarchies of power.

Eugenics did not function only "in the service of a biological struggle between nation-states" (Rose 2007, 66); it functioned to maintain the racial, gender, and class order within the nation. (Moreover, alliances between American and Nazi eugenicists in the 1930s show a willingness to cross national boundaries in the interest of white supremacy.)[21] Thus, contemporary proposals to solve social problems by curbing black reproduction, such as the *Philadelphia Inquirer*'s suggestion to distribute the long-acting contraceptive Norplant as a remedy for black poverty, are similar to past eugenic policies in that they make racial inequality appear to be the product of nature rather than power (Kimelman 1990). By identifying procreation as the cause of black people's condition, they divert attention away from the political, social, and economic forces that maintain the U.S. racial order. I therefore believe it is accurate and helpful to identify the ways in which contemporary reproductive health policies incorporate essential features of eugenic ideology, despite the important differences that Rose highlights.

Furthermore, the distinction between past state-imposed and current voluntary programs is not as clear-cut as Rose suggests. On the one hand, Rose ignores the system of punitive governance that accompanies the neoliberal shift to individual self-governance. Welfare is no longer a system of aid but rather a system of behavior modification that attempts to regulate the sexual, marital, and childbearing decisions of poor unmarried mothers by placing conditions on the receipt of state assistance (Roberts 1998; Mink 2002; Smith 2007). Meanwhile, federal and state governments aggressively intervene in marginalized communities to manage their social deprivation with especially punitive measures. The U.S. prison population has grown to proportions unprecedented in the history of Western democracies, as an astounding number of young black men are locked up (Garland 2001; the Sentencing Project 2005). The racial disparity in the foster care population mirrors that of the prison system, as child protection authorities remove grossly disproportionate numbers of black children from their homes (Roberts 2002). Population control policies that attribute social inequities to the childbearing of poor minority women are a critical component of this punitive trend away from state support for families and communities (Roberts 1998; Smith 2007). Rose's reference to "the enabling state, the facilitating state, the state as animator" (2007, 63) does not apply to policies designed to penalize childbearing by poor women and women of color.

On the other hand, Rose's focus on state direction of twentieth-century eugenic programs obscures the crucial role of private enterprises in disseminating and implementing eugenics. Just as influential as the mandatory sterilization laws passed in most states were the campaigns waged by private groups such as the American Eugenics Society, the Human Betterment Association, and the American Genetics Association to educate the American public about the benefits of eugenics, as well as the American Birth Control League's programs to distribute birth control to the unfit (Kevles 1985). As Rose acknowledges, "Eugenics was not disreputable or marginal: it defined one dimension of mainstream thinking about the responsibilities of politicians, professionals, scientists, and individuals in the modern world" (2007, 59).

Some feminists who use eugenics rhetoric to critique modern genetic selection technologies explicitly acknowledge the distinction between state-imposed programs and private decisions made by individuals. For example, U.S. sociologist Barbara Katz Rothman calls the marketing of prenatal diagnostic technologies a form of microeugenics, focused on the individual, in contrast to macroeugenics, focused on populations (2001). I also explicitly distinguish between population control policies and those that promote reprogenetics while drawing attention to their common support of neoliberal approaches to social inequities (Roberts 2005). This distinction, however, should not eclipse the coercive nature and social function of contemporary reprogenetics (Wendell 1996, 156; Ward 2002). As I discuss above, genetic selection procedures are increasingly treated as social responsibilities reinforced not only by cultural expectations but also by legal penalties and incentives. Does the state-supported reproductive genetics industry exist only to give individual citizens more reproductive choices, or, as Laura Hershey asks, is it "primarily for the benefit of a society unwilling to support disability-related needs?" (1994, 31; see also Wendell 1996, 154).

Rose's analysis of contemporary biopolitics helps to illuminate the radical change from state management of the population's health to individual management of genetic risk, aided by new genetic technologies. These technologies facilitate the shift from state responsibility for ensuring health and welfare to private responsibility, all within the context of persistent race, gender, and class inequities; devastating reductions in social programs; and intense state surveillance of marginalized communities. Genetic screening is increasingly recommended not only to avoid having children with serious early onset disabilities or diseases with a high likelihood of occurring but to eliminate the risk of developing certain diseases as an adult (Obasogie 2006). A recent article in the *Journal of the American Medical Association,* for example, encouraged families affected by hereditary cancer syndromes, including breast, ovarian, and colon cancer, to use PGD to screen out embryos genetically predisposed to develop cancer (Offit, Sagi, and Hurley 2006). In the neoliberal future, the state may rely on the expectation that all pregnant women will undergo genetic testing to legitimize not only its refusal to support the care of disabled children but also its denial of broader claims for public provision of health care.

EXTENDING CHOICE TO WOMEN OF COLOR

The role reprogenetics plays in neoliberalism's integrated system of privatization and punitive governance is obscured by liberal notions of reproductive choice. Despite the potential for reprogenetics to diminish public health care and intensify regulation of women's reproductive decisions, its sponsors often defend the industry's immunity from state regulation in the name of women's reproductive freedom (Rothman 1989, 116; Darling 2004a). Extending the availability of genetic selection technologies to women of color does not correct the role played by reprogenetics in advancing a neoliberal agenda. The depletion of public resources for general health care and for supporting people with disabilities would exacerbate economic inequities along racial lines, hitting poor minority communities the hardest. In addition, the expectation of genetic self-regulation may fall especially harshly on black and Latina women, who are stereotypically defined as lacking the capacity for self-control. The use of high-tech, expensive technologies by a privileged slice of women of color suggests that those who do not use them for financial, social, or ethical reasons may be blamed for the social consequences.

There may always be certain reproductive technologies that are reserved for the wealthiest people and are outside the reach of most women of color. The market will privilege a tiny elite among people of color who can afford high-tech reproductive innovations while relegating the vast majority to the state's most intense reproductive surveillance. Indeed, the neoliberal reification of market logic is likely to expand the hiring of poor and low-income women of color for their reproductive services. The incidence of payments to these women to gestate fetuses or to produce eggs for genetic research could intensify (Haworth 2007) even as they are encouraged to use genetic technologies to screen their own children.

In addition, marketing race-based biotechnologies to consumers of color can reinforce the biological meaning of race. By incorporating invented racial categories into genetic research, scientists and entrepreneurs are producing biotechnologies that validate people's belief that race is a natural classification. A renewed trust in inherent racial differences provides an alternative explanation for persistent gross inequities in blacks' health and welfare despite the end of de jure discrimination. These technologies promote the view that deepening racial inequities that result from neoliberal policies are actually caused by genetic differences between whites and other racialized groups. The biological explanation for racial disparities provides a ready logic for the staggering disenfranchisement of people of color through mass incarceration and other punitive policies, as well as the perfect complement to color-blind policies implementing the claim that racism has ceased to be the cause of their predicament. Including women of color in the market for reprogenetic technologies does not eradicate the racial caste system underlying reproductive stratification.

A reproductive dystopia for the twenty-first century could no longer exclude women of color from the market for high-tech reprogenetics. Rather, it would take place in a society in which racial and economic divisions are reinforced by the genetic testing extended to them. In this new dystopia, the biological definition of race is stronger than ever, validated by genetic science and cemented in popular culture by race-based biotechnologies. The state has disclaimed all responsibility for supporting its citizens, placing the duty of ensuring public welfare in all women's self-regulation of genetic risk. The medical model of disability is embedded in a neoliberal health policy that relies on widespread use of genetic technologies to disqualify citizens from claiming public support and to avoid the need for social change. The new biologization of race may seem to unite blacks, and other nonwhite "races," by confirming the genetic uniformity of people belonging to the same race and their genetic difference from others. In the new dystopia, however, genetic selection technologies that incorporate race as a biological category reinforce class divisions between elite people of color who can afford the full array of high-tech procedures and the masses who suffer most from neoliberal policies bolstered by these very biological explanations of racial inequities. But I can also imagine a new utopia arising from feminists' radical resistance to enlisting women as genetic screeners in service of a neoliberal agenda, a resistance that is emboldened by new alliances—joining reproductive justice with antiracist, disability rights, and economic justice movements that recognize their common interest in contesting a race-based reprogenetic future.

NOTES

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1. See the Reprogenetics Web site at http://www.reprogenetics.com/default.html.
2. See the Web sites of DNA Tribes (http://www.dnatribes.com), GeneTree (http://www.genetree.com), and National Geographic's Genographic Project (https://www3.nationalgeographic.com/genographic/index.html).
3. See the Pacific Fertility Center's appeal to prospective donors at http://www.donateyoureggs.com and information about egg donation at http://www.pacificfertilitycenter.com/treat/agency_donation.php.
4. Johnson v. Calvert, 5 Cal. 4th 84, 19 Cal. Rptr. 494 (1993), cert. denied, 114 S. Ct. 206 (1993).
5. See the Rinehart Center for Reproductive Medicine Web site at http://www.illinoisivf.com.
6. See the Sher Institutes for Reproductive Medicine Web site at http://www.haveababy.com/ss/index_ss.cfm?&cityplocal&sitepss2.

7. See Genetics and IVF Institute, advertisement, *New York Times Magazine,* July 29, 2007, 21.
8. See images of the "baby picnic" at http://www.reproductivespecialist.com/baby_parties.htm.
9. See the Houston IVF Web site at http://www.houstonivf.net/houstonivf/OurServices/ OurServices.asp.
10. For images from the Karande and Associates Web site, see http://www.karandeivf.com/appoint ment.html, http://www.karandeivf.com/eggd onorprogram.html, and http://www.karandeivf.com/insurance.html.
11. See Beverly Hills Egg Donation, advertisement, Los Angeles craigslist.com, SF Valley, etcetera jobs, November 22, 2008.
12. See F. Williams Donor Services, advertisement, Inland Empire craigslist.com, etcetera jobs, November 24, 2008.
13. See Happy Beginnings, LLC, advertisement, Reno craigslist.com, etcetera jobs, November 13, 2008.
14. See the Pacific Fertility Center's appeal to prospective donors at http://www.donateyour eggs.com.
15. See the Pacific Fertility Center's Web site at http://www.pacificfertilitycenter.com/treat/agency_donation.php.
16. See the Reproductive Genetics Institute's Web page on first trimester screening at http://www.reproductivegenetics.com/first_trimester.html.
17. For example, the Supreme Court of Ohio recently held that parents of an unhealthy child born following negligent failure to diagnose a fetal defect or disease may bring suit under traditional medical malpractice principles for the costs arising from the pregnancy and birth of the child: Schirmer v. Mt. Auburn Obstetrics and Gynecologic Associates, Inc., 108 Ohio St. 3d 494, 2006-Ohio-942 (Ohio S. Ct. 2006). For an argument in favor of using tort law to compensate for "procreative injury" caused by reproduction assisting technologies, see Kleinfeld (2005).
18. For an extensive review of insurance coverage of infertility treatments, see Arons (2007, 8–13): "Fourteen states currently require some types of health insurance plans to include coverage of certain infertility services or to make such coverage available" (8).
19. PGD also serves to increase fertility when it is undertaken to improve IVF success rates (Franklin and Roberts 2006, 97).
20. A recent survey of research on the experience of disability in families concluded, "There is an increasingly dominant body of research that finds aggregate patterns of overall adjustment and well-being to be similar across groups of families with and without children with disabilities" (Ferguson, Gartner, and Lipsky 2007, 85).
21. When the leading American eugenicist, Harry Laughlin, received an honorary degree from the University of Heidelberg in 1936, he wrote to German officials that the award represented "evidence of a common understanding of German and American scientists of the nature of eugenics" (quoted in Kevles 1985, 118).

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CHAPTER 20

Sexing the X: How the X Became the "Female Chromosome"

Sarah S. Richardson

"Unexpected." "Counterintuitive." "Intellectually surprising."[1] These were among the exclamations of researchers upon the 2001 discovery that the human X chromosome carries a large collection of male sperm genes (Wang et al. 2001). Although both males and females possess an X chromosome, the X is frequently typed as the "female chromosome" and researchers assume it carries the genes for femaleness. This essay traces the origins of this long-standing and infrequently questioned association of the X with femaleness and examines the influence of this assumption on historical and contemporary genetic theories of sex and gender difference.

Humans possess twenty-two pairs of autosomal chromosomes and one pair of sex chromosomes—X and Y for males, X and X for females. Today it is well established that the Y carries a critical genetic switch for male sex determination. The X, however, has no parallel relationship to femaleness. Female sexual development is directed by hormones acting in concert with genes carried by many chromosomes and is not localized to the X. Indeed, the X is arguably more important to male biology, given the large number of X-linked diseases to which men are uniquely exposed. Despite this, researchers attribute feminine behavior to the X itself and assume that female genes and traits are located on it. Researchers look to the X to explain sex differences and female quirks and weaknesses and have argued that men are superior because they possess one fewer X than females.

The X chromosome offers a poignant example of how the gendering of objects of biological study can shape scientific knowledge. Moving freely between stereotypical conceptions of femininity and models of the X chromosome, X-chromosomal theories of sex differences reveal a circular form of reasoning that is familiar in gender analysis of biology. As Evelyn Fox Keller writes: "A basic form common to many [feminist analyses of science] revolves around the identification of synecdochic (or part for whole) errors of the following sort: (a) the world of human bodies is divided into two kinds, male and female (i.e., by sex); (b) additional (extraphysical) properties are culturally attributed to these bodies (e.g., active/passive, independent/dependent, primary/secondary: read *gender*); and (c) the same properties that have been ascribed to the whole are then attributed to the subcategories of, or processes associated with, these bodies" (1995, 87). A classic historical example of this phenomenon is the gendering of the egg and sperm in mid-twentieth-century medical textbooks, documented by Emily Martin (1991). A second example is the gendering of the sex steroids estrogen and testosterone, as told by Nelly Oudshoorn (1994) and Anne Fausto-Sterling (2000).

Rooted in history and philosophy of science, and drawing on the interdisciplinary methods and questions of feminist science studies forged by scholars such as Fausto-Sterling, Keller, Donna Haraway, and Martin, this essay investigates the sexing of the X in a variety of scientific materials both internal and external to the biosciences. The sexing of the X, I argue, represents a case of gender-ideological bias in science, both historically and in the present day. More generally, it demonstrates how biological objects and concepts may take on a gendered valence as they circulate between popular and scientific realms.

The female X has its roots in early sex chromosome science, which assumed for half a century—until the 1950s, when the Y was confirmed as the carrier of the sex-determining locus—that the X was female determining in humans. In the first part of what follows, I document the contingent technical, material, and ideological factors that led to the feminization of the X during the first decades of sex chromosome research and track the introduction of the "female chromosome" into human genetics at midcentury. In the second part, I demonstrate the continuing influence of the historical feminization of the X on genetic research, exemplified by "X chromosome mosaicism" theories of female biology, behavior, and disease. Focusing on the case of X-mosaicism theories of the higher incidence of autoimmunity in women, I show how the assumption that the X is the female chromosome operates to sustain and cohere hypotheses of dubious empirical merit in research areas urgently relevant to women's health.

THE FEMININE CHROMOSOME

Scientific and popular literature on the sex chromosomes is rich with examples of the gendering of the X and Y. The X is dubbed the "female chromosome," takes the feminine pronoun "she," and has been described as the "big sister" to "her derelict brother that is the Y" (Vallender, Pearson, and Lahn 2005, 343) and as the "sexy" chromosome (Graves, Gecz, and Hameister 2002). The X is frequently associated with the mysteriousness and variability of the feminine, as in a 2005 *Science* article headlined "She Moves in Mysterious Ways" and beginning, "The human X chromosome is a study in contradictions" (Gunter 2005, 279). The X is also described in traditionally gendered terms as the more sociable, controlling, conservative, monotonous, and motherly of the two sex chromosomes. Similarly, the Y is a "he" and ascribed traditional masculine qualities—macho, active, clever, wily, dominant, as well as degenerate, lazy, and hyperactive.[2]

There are three common gendered tropes in popular and scientific writing on the sex chromosomes. The first is the portrayal of the X and Y as a heterosexual couple with traditionally gendered opposite or complementary roles and behaviors. For instance, MIT geneticist David Page says, "The Y married up, the X married down. . . . The Y wants to maintain himself but doesn't know how. . . . He's falling apart, like the guy who can't manage to get a doctor's appointment or can't clean up the house or apartment unless his wife does it" (Dowd 2005). Biologist and science writer David Bainbridge (2003) describes the evolutionary history of the X and Y as a "sad divorce" (56) set in motion when the "couple first stopped dancing," after which "they almost stopped communicating completely" (58). The X is now an "estranged partner" of the Y, he writes, "having to resort to complex tricks" (145). Oxford University geneticist Brian Sykes (2003) similarly describes the X and Y as having a "once happy marriage" (283–84) full of "intimate exchanges" (42–43) now reduced to only an occasional "kiss on the cheek" (44). A 2006 article on X-X pairing in females in *Science* by Pennsylvania State University geneticist Laura Carrel is headlined "'X'-Rated Chromosomal Rendezvous" (2006).

Second, sex chromosome biology is often conceptualized as a war of the sexes. In Matt Ridley's *Genome: The Autobiography of a Species in 23 Chapters* (1999), the chapter on the X and Y chromosomes is titled "Conflict" and relates a story, straight from *Men Are from Mars, Women Are from Venus* (Gray 1992), of two chromosomes locked in antagonism and never able to understand each other (Ridley 1999, 107). A 2007 *ScienceNOW Daily News* article similarly insists on describing a finding about the Z chromosome in male birds (the equivalent of the X in humans) as demonstrating "A Genetic Battle of the Sexes" (Pain 2007), while Bainbridge (2003) describes the lack of a second X in males as a "divisive . . . discrepancy between boys and girls" (83), a genetic basis for the supposed war of the sexes.

Third, sex chromosome researchers promote the X and Y as symbols of maleness and femaleness with which individuals are expected to identify and in which they might take pride. Sykes offers the Y chromosome as a totem of male bonding, urges males to celebrate their unique Y chromosomes, and calls for them to join together to save the Y from extinction in his 2003 *Adam's Curse: A Future without Men*. Females are also encouraged to identify with their Xs. Natalie Angier (1999) urges that women "must take pride in our X chromosomes. . . . They define femaleness" (26). The "XX Factor" is a widely syndicated column about women's work/life issues on Slate.com, with the slogan "What Women Really Think"; it is also the name of an annual competition for female video gamers.[3] The promotional video for the Society for Women's Health Research, designed to convince the viewer of how very different men and women really are, is titled "What a Difference an X Makes!" (Society for Women's Health Research 2008).

HOW THE X BECAME THE FEMALE CHROMOSOME

The notion of the X as the female chromosome arises from its history as an object of research and its ensuing gendered valence within biological and popular theories of sex. It was originally assumed that the X, not the Y, was the sex-determining chromosome in humans. Theophilus S. Painter, the American cytogeneticist who in 1924 first described the human sex chromosomes, dubbed XX "the female chromosome complex" (1924, 509), the X the "female-producing chromosome" (509), and males as "heterozygous for sex" (522), as they possess only one X. This founding idea, that the X is "female-producing" (509) or female tending, focused theories of the biological determination of femaleness exclusively on the X well into the twentieth century.

Historically contingent technical and material factors also helped to brand the X as female. The dominance of studies of the fruit fly *Drosophila* in the first half-century of genetic research played a central role. Unlike in mammals, in *Drosophila* the X is female determining. This is a threshold effect, in which sex is determined by the ratio of autosomes to X chromosomes, with more Xs producing femaleness. In textbook explanations of sex chromosomes from the first quarter of the century, an ink drawing of *Drosophila* chromosomes was ubiquitously used to illustrate the section on the chromosomal theory of sex (Morgan 1915, 7; Wilson 1925). So pervasive were *Drosophila*'s X and Y as the model for the sex chromosomes that the leading American geneticist, Thomas H. Morgan, dubbed the XX/XY chromosome constitution the "Drosophila type," writing that "The genetic evidence so far gained has placed in the Drosophila type the following animal forms: Drosophila, man, cat; and the plants, *Lychnis* and *Bryonia*" (1915, 78–79). The *Drosophila* model suggested that in humans, as in flies, the X should be expected to determine femaleness.

In the early days chromosomes were also studied almost exclusively in male gametes—the sperm. Looking at sperm, which as reproductive cells possess only one member of each chromosome set, a perfect dichotomy appeared: half the sperm cells had the X, and half did not. This led to a hyperbinary view of the X and Y. The sperm with an X always produces a female, and the X in the males' sperm is always inherited from the female parent. Failing to distinguish between the "sex" of the gamete and the sex of the organism, this distorted perspective helped to prematurely assign the X to femaleness.

Cytologists were originally "spermatologists" (Voeller 1968, 78–80), and spermatology played a large role in setting the research agenda, context, and motivation for sex chromosome studies. Sperm are plentiful, accessible, and easier to study than eggs or other human tissue. Thus, there are good reasons that male gametes were early chromosome researchers' tissue of choice. Nonetheless, the focus on sperm introduced a bias into early sex chromosome research. The centrality of maleness and male tissue to this research led scientists to the conclusion that the X is female and the Y is male. Had researchers looked at somatic tissue, the dichotomy would have been far less clear-cut: both males and females possess at least one X.

The human cytogenetic research revolution of the late 1950s and 1960s, which revealed that it is the Y that determines sex, marked the demise of the X-chromosomal model of human femaleness. After World War II, human genetics research reemerged in the wake of massive US investments in education, life science research, and medicine. Charged with the task of assessing the long-term health and biological consequences of nuclear fallout, human cytogenetics—the study of the structure, behavior, and function of human chromosomes—burst onto the scene in the 1950s with a series of profound and triumphant discoveries. These included confirmation that humans possess forty-six chromosomes (rather than forty-eight, as had been universally believed); the revelation that an extra chromosome 21 causes Down syndrome; the understanding that the Y, not the X, is sex determining; and the identification, through population screening, of a host of surprisingly common human sex chromosome anomalies (see de Chadarevian 2006; Harper 2006).

The first significant breakthrough for human sex chromosome research was the identification of a condensed body present only in female cells. Discovered in 1949, the Barr body, an artifact of the presence of two X chromosomes, suddenly allowed nuclear sexing of any human cell (Barr and Bertram 1949). Murray Barr described the revelation that the "nuclei bear a clear imprint of sex" (Barr 1959, 681) as the "principle of nuclear sexual dimorphism" (682). The notion that every cell has a sex shifted the terms of human sex research and ushered sex difference into the genetic age. Screening for the presence of a Barr body allowed sex chromosome aneuploidies (numerical errors), such as Turner syndrome (XO) and Klinefelter syndrome (XXY), as well as a host of exotics, such as XXXs, XXXYs, XYYs, to be detected well before more detailed chromosome analysis and visualization techniques became available.

By the 1960s, human sex chromosome aneuploidies and other chromosomal anomalies had become potent symbols of the fascinating and exciting new genetics. The historian of midcentury genetics Soraya de Chadarevian (2006, 724–25) argues that this chromosome symbolism, along with the representational schema of the human karyotype, was the public icon of modern genetics in the 1950s and 1960s, before the double helix took its place. It was through this imagery, and the novelty of sex chromosome aneuploidies, that the public first became widely conscious of the X and Y as the molecular pillars of biological femaleness and maleness.

The official findings of human cytogenetics of the 1950s and 1960s were as follows: Human males and females possess twenty-two pairs of autosomes and a pair of sex chromosomes. Males have an X and a Y, and females have two X chromosomes. In females one X in each cell is inactivated early in development, equalizing dosage of X-chromosomal genes in males and females. Subsequent research revealed that the Y chromosome primarily carries a gene that initiates male sexual development and bears few other genes. In contrast, the X chromosome is similar to an autosome, with more than a thousand genes. The X plays no special role in female development, which is controlled by a variety of genes on several different chromosomes.

The idea that the X was female determining was promptly discarded in light of these new findings. The female or feminine resonance that had accumulated around the X chromosome, however, did not fall away. As Fiona Alice Miller (2003) notes with respect to the term "Mongolism" for trisomy 21 (Down syndrome), "Contrary to conventional beliefs about new, breakthrough technologies, the introduction of chromosome analysis in the late 1960s did not displace existing standards of interpretation and practice" (76). Old habits and the force of the idea of a molecular gender binary revealed in the X and Y were irresistible. As the Y would be the male chromosome, the X would continue to be the female one.

Researchers did not give up the search for a relationship between the double X and femaleness in the wake of the 1959 finding that the Y is sex determining. They would continue to ask: What does the extra X do for females? What does an exposed, single X do for males? Elaborated in human genetics over the coming decades, the X and Y became sites for the enactment and rediscovery of traditional gender roles and stereotypes.

X-CHROMOSOMAL THEORIES OF HUMAN SEX DIFFERENCES

The question of whether the second X bestows human females with something extra, or whether it is more advantageous to have a single X chromosome, a question charged with gender politics, stalked the X from its earliest appearance in the public and scientific consciousness. Though human chromosome research was sporadic prior to the 1950s, the notion that human females carry an extra chromosome found its way into the scientific and social discourse around gender, a discourse that seems to have widely accepted the idea that the facts of biology would help to settle the sex wars and that we should expect to find definitive proof in the X of a sexual hierarchy.

On one side was the idea that double-X females are superior, advantaged, or special as a result of their extra X. This was appropriated by women's advocates: "The ancient idea that the female is essentially an undeveloped male seems to be finally disproved by the fact that it requires more determiners—usually one more chromosome, or a larger sex chromosome—to produce a female than a male," pronounced the feminist psychologist Helen Thompson Woolley (1914, 354). Even the notorious antifeminist Louis Berman conceded in his 1921 *The Glands Regulating Personality* that biologists could no longer seek the source of female inferiority in the chromosomes: “For the time being, let the feminists glory in the fact that they have two more chromosomes to each cell than their opponents. Certainly there can be no talk here of a natural inferiority of women” (1921, 136).[4] The anthropologist and public intellectual Ashley Montagu marshaled the notion of female X chromosome advantage in his 1953 text *The Natural Superiority of Women.* In a chapter titled “‘X’ Doesn’t Equal ‘Y,’” Montagu argued that it is “to the presence of two well appointed, well furnished X-chromosomes that the female owes her biological superiority” (1953, 76). Males, with their “X-chromosomal deficiency” (76), fall prey to such diseases as hemophilia and colorblindness, and countless other speculated weaknesses, while females, owing to an extra X, are “constitutionally stronger than the male” (81). Montagu asserted that females’ extra X “lies at the base of practically all the differences between the sexes and the biological superiority of the female to the male” (74).

The discourse of female X-chromosomal superiority persisted in the second half of the twentieth century and even continues today. The size of the X and its large number of genes is frequently celebrated, and great emphasis is placed on the notion that, due to the second X, females have more genetic material than males. For example, *Time* magazine reported in 1963: “Because the X chromosome is so much bigger than the Y, women with two X’s have 4 percent more genetic material—the vital deoxyribonucleic acid, or DNA—than men. Geneticists have speculated that this might explain women’s longer life span. . . . [This] definitely gives women an inherent advantage over men” (“Research Makes It Official,” 1963). Johns Hopkins geneticist Barbara R. Migeon argues that the second X means that “females have a little extra determinant” compared with males, which “bestows a remarkable biological advantage” (2007, 208). “When it comes to the battle of the sexes,” writes E.J. Mundell (2007), reporting on Migeon’s work, “nature hands women extra ammunition right from the start. The reason, according to geneticists: Females are gifted with two copies of the powerful X chromosome, while males are born with only one X, plus the relatively weak Y chromosome.” Migeon, whose research I will return to below, even argues that the extra genetic material might account for why females and males have a different sense of humor and could explain why “from the first days of school, girls outperform boys, are more attentive, and are more persistent at tasks” (2006, 1432–33).[5]

Countering claims of female X-chromosome superiority has been the far more influential notion that females are the weaker sex precisely because they carry an extra X chromosome. In the early twentieth century, prominent scientists asserted that the single X provided the biological mechanism for superior male cognition. They argued that while the single X may subject males to damaged genes on the X, it also exposes them more wholly to advantageous genes. The risks that males take with their sole X are countered by rich potential rewards. While females enjoy the security of a second X, it dulls their potential for extraordinariness. Males are superior where it counts: intelligence.

Highly influential in sex difference research, the “greater male variability” theory of male intellectual superiority framed research on cognitive differences between males and females from the 1870s to the 1930s. It was subsequently discredited with the rise of new experimental techniques, greater statistical sophistication, and large-scale empirical psychological testing. These studies showed no significant differences between males and females in overall intelligence and demonstrated that, while men were more likely to be at the very low end of the IQ scale, they were not equally likely to be at the high end.

Charles Darwin was among the most prominent adherents of the concept of greater male variability. In *The Descent of Man* ([1871] 1897), he argued that males are the engine of evolution, accumulating variations that lead to species divergence and evolution. For this reason, he wrote, “Man is more courageous, pugnacious, and energetic than woman, and has a more inventive genius” (557). In the nineteenth and early twentieth centuries, the principal evidence for the greater male variability hypothesis was the long-observed predominance of males among residents of what were then known as institutions for the “feeble-minded” and, conversely, among the ranks of genius and the socially eminent. Early twentieth-century observations of an excess of males among the intellectually disabled and documentation of a large number of mentally impairing X-linked conditions exclusive to males led to speculations that the single X was a mechanism for the observed “greater variability” in male intellect—and that the double X was a source of female dullness (Stevenson et al. 1994, 538).

The earliest geneticist to attach the X to male variability and female conservatism was Clarence E. McClung (1899, 1902), who first discovered the link between the X and sex. McClung later wrote of the X chromosome, “It is possible that we have here the explanation of the greater variability of the male” (1918, 162). He continued, “There is a possibility that in the male, the sex [X] chromosome being unmated, or opposed by an inactive element, may be more free to react with the other chromosomes and in this way change their constitution, being in turn affected by the reaction. By the nature of its transmission it must, after this experience, pass into the female line where its relation to the complex is necessarily different. The contrast in these two conditions is obvious and the interpretation strongly suggested” (162). The X-chromosomal theory of male intellectual superiority cyclically resurfaced in sex difference research throughout the twentieth century, and continues to lurk in X chromosome studies today. As the BBC reported in 2005: “Men also have another reason for feeling upbeat about their genetic lot. *New Scientist* reports that although men are more likely to be mentally retarded, they are also more likely to be geniuses. Although the average IQ of men and women is equal, men are more frequently found at both extremes of intelligence. This is because, if you have very good intelligence genes on your X chromosome, it pays not to have them muffled by more average genes on another X chromosome” (Kettlewell 2005). Robert Lehrke’s *Sex Linkage of Intelligence* (1997) exhumes and reasserts, in near entirety, the greater male variability theory of the late nineteenth and early twentieth centuries. Ongoing research programs at the Medical Research Council in London and University of California–Los Angeles in the United States continue to engage in X chromosome research on the subject—a pursuit that has only been heightened in the wake of the sequencing of the human X in 2005. As a *Nature* article puts it, today “the ‘feminine’ X chromosome is a prime hunting ground for geneticists interested in the evolution of the cognitive and cultural sophistication that defines the human species” (Check 2005, 266).

TRACKING THE FEMALE X INTO HUMAN GENETICS

The cases of Turner and Klinefelter syndromes demonstrate how the idea of the female-engendering X was carried forward into the human genetics era and how the notion of the female chromosome continued to inflect reasoning about human health and biology even after the X was found not to determine femaleness in humans. Both Turner and Klinefelter were well-documented syndromes of gonadal dysgenesis prior to human chromosome research. Physicians in the United States identified Turner syndrome in 1938 as a syndromic—meaning characterized by a complex of symptoms not localized to any single organ system—phenotype found exclusively in women. Traits included short stature, infertility, and neck webbing (Turner 1938). A Massachusetts General Hospital physician described Klinefelter syndrome in 1942 as a disorder of gonadal underdevelopment in males, resulting in hormonal deficiencies causing infertility and limited body hair (Klinefelter, Reifenstein, and Albright 1942).

Barr body screening in the 1950s revealed that Turner females lack a second X and that Klinefelter males carry an extra X. Once associated with sex chromosome aneuploidy in the 1950s, the disorders were redescribed in more strongly sexed and gendered terms. The infertility of the XO Turner woman was portrayed as evidence of her masculinity rather than a disorder of female sexual development and of development in general. Turner women were claimed to have masculine cognitive traits such as facility with spatiality, discomfort with female gender roles, and defeminized body shape. XXY Klinefelter males were portrayed as feminine, with much emphasis on their purportedly unmuscular body frame, female body-fat distribution, lack of body hair, and infertility. The eminent British geneticist Michael Polanyi even proposed that XO females were "sex-reversed males" (Harper 2006, 79). Patricia A. Jacobs and John Anderson Strong (1959) described an XXY individual as "an apparent male . . . with poor facial hair-growth and a high-pitched voice" (302). They continued, "There are strong grounds, both observational and genetic, for believing that human beings with chromatin-positive nuclei are *genetic females* having two X chromosomes. The possibility cannot be excluded, however, that the additional chromosome is an autosome carrying feminizing genes" (302). A 1967 *New York Times* article similarly captures this mode of reasoning. With the headline "If her chromosomes add up, a woman is sure to be woman," it describes XXY males as having "a few female traits" (Brody 1967, 28). Studies were even undertaken to determine whether Turner women show a tendency toward lesbianism or Klinefelter men incline toward homosexuality or cross-dressing.[6]

These assumptions about the X as feminizing distorted understanding of these disorders, stigmatized individuals carrying them, and misdirected research and clinical care. Today, clinicians specializing in Klinefelter and Turner management emphasize that these are not diseases of gender confusion. Klinefelter patients are phenotypic males, and Klinefelter is not a syndrome of feminization. We now know that Klinefelter is one of the most common genetic abnormalities and often has so few manifestations that men live out their lives never knowing of their extra X. Writes Robert Bock (1993), "For this reason, the term 'Klinefelter syndrome' has fallen out of favor with medical researchers. Most prefer to describe men and boys having the extra chromosome as 'XXY males.' " Similarly, XOs are phenotypic females. Turner syndrome, which has more profound and systemic phenotypic effects than XXY, is emphatically not a masculinizing condition. Physical deformities, heart trouble, infertility, and, occasionally, social and cognitive difficulties are the principal concerns for Turner females.

Throughout the history of twentieth-century genetics, gendered conceptions of the X chromosome fueled ideological conceptions of femaleness and maleness. Today the conception of the X as the female chromosome is not obsolete. It remains a common assumption in twenty-first-century genomics and a source of distortion and bias in genetic reasoning. We have already visited, briefly, some of the areas in which the female chromosome appears in contemporary biomedical research: the surprise over the finding of spermatogenesis genes on the X chromosome and X-linked theories of sex differences in intelligence. Perhaps the most prominent case of how the sexing of the X as female continues to operate today, however, is found in "X mosaicism" theories of female biology, health, and behavior.

FEMALE X MOSAICISM

Mammalian females are genetic mosaics for the X chromosome. In order to equalize the expression of X-linked gene products in males and females, one of the Xs in each somatic cell is randomly inactivated early in female development. Approximately half of a female's cells will express the maternal X chromosome and half the paternal X chromosome. Thus, females have two populations of cells, identical with respect to the twenty-two pairs of autosomes but variable in X-chromosomal gene expression when females carry functionally different versions of an X-chromosomal allele.

X mosaicism has some implications for human female biology. Random X inactivation early in development leaves most women with a 50 : 50 ratio of cells expressing either their paternal or maternal Xs. As a result, females carrying a disease allele on one of their X chromosomes will generally not develop the disease, since cells carrying the other X usually produce adequate amounts of the needed gene product to compensate for any dysfunction. For this reason, X mosaicism shields females from X-linked diseases. Classic X-linked diseases such as Duchenne muscular dystrophy or hemophilia are infrequent in women and generally affect only men.

In rare cases, X mosaicism will begin to skew, resulting in tissues biased toward the maternal or paternal X chromosome. Tissues grow clonally, so skewing can happen randomly as a result of a bias in the cells from which the tissue grows. As we age, chromosomes fray, whither, and disappear due to the erosion of genetic repair mechanisms, making skewing more common. Usually, skewed X mosaicism has no phenotypic consequence and goes unnoticed. If a woman carries an X chromosome disease allele, however, extreme skewed X inactivation leading to dominance of the chromosome carrying the disease-causing allele can, in rare cases, cause women to exhibit classic X-linked diseases generally restricted to men. Thus, the primary clinical implication of skewed X mosaicism for females is that it may leave them functionally monosomic for the X—like males—making them vulnerable to male-typical X-linked diseases.

Developed in the 1960s by British cytogeneticist Mary Lyon, the X inactivation hypothesis began as a theory of an evolutionary fix that could equalize the X gene product between males and females (Lyon 1992). It was transformed in the 1980s and 1990s into a theory of genetic difference between males and females, and among females. Today, X chromosome mosaicism, the consequence of random X inactivation, is strongly identified with femaleness and used loosely and flexibly, often without any gesture toward experimental validation, to explain biological sex differences. The identification of the X with females, the cultural association of females with chimerism, and the assumption that the sex binary observed in the world will eventually be revealed at the molecular level help to fill in the gaps in the X mosaicism theory of sex differences, veil its empirical deficiencies, and glue its premises together.

GENDER IN X MOSAICISM RESEARCH

From its inception, the hypothesis that females are cellular mosaics for X-chromosomal genes was received as confirmation of dominant cultural assumptions about gender difference. The characterization of females as mosaics or chimeras resonated with conceptions of women as more mysterious, contradictory, complicated, emotional, or changeable.[7] The future Nobel laureate molecular biologist Joshua Lederberg wrote in 1966, "The chimerical nature of woman has been a preoccupation of poets since the dawn of literature. Recent medical research has given unexpected scientific weight to this concept of femininity" (1966, E7).[8] Reporting on the new finding in 1963, *Time* magazine asserted that "the cocktail-party bore who laces his chatter with the tiresome cliché about 'crazy, mixed-up women' has more medical science on his side than he knows. . . . Even normal women, it appears, are mixtures of two different types of cells, or what the researchers call 'genetic mosaics'" ("Research Makes It Official," 1963).

Today, the notion of X mosaicism as scientific confirmation of traditional ideological conceptions of female instability, contradiction, mystery, complexity, and emotionality is thoroughly entrenched. As science writer Nicholas Wade told the *New York Times* in 2005, "Women are mosaics, one could even say chimeras, in the sense that they are made up of two different kinds of cell. Whereas men are pure and uncomplicated, being made up of just a single kind of cell throughout" (Dowd 2005). A 2005 Pennsylvania State University press release similarly announced, "For every man who thinks women are complex, there's new evidence they're correct; at least when it comes to their genes" ("Men and Women," 2005).

These metaphors and gender assumptions are widely shared by present-day sex chromosome researchers. Duke University geneticist Huntington Willard, for instance, is quoted saying, "Genetically speaking, if you've met one man, you've met them all. We are, I hate to say it, predictable. You can't say that about women," and Massachusetts Institute of Technology geneticist David Page says, "Women's chromosomes have more complexity, which men view as unpredictability" (Dowd 2005). British geneticist Robin Lovell-Badge has similarly said that "10% [of genes on the X] are sometimes inactivated and sometimes not, giving a mechanism to make women much more genetically variable than men. I always thought they were more interesting!" (Kettlewell 2005).

Barbara Migeon, the Johns Hopkins X chromosome geneticist mentioned above and author of the book *Females Are Mosaics* (2007), is a leading promoter of the theory that X mosaicism is a fundamental mechanism of sex differences and a hallmark of female biology and behavior. Migeon claims that "somatic cellular mosaicism . . . has a profound influence on the phenotype of mammalian females" (1994, 230). According to Migeon, X mosaicism "creates biological differences between the sexes that affect every aspect of their lives, not just the sexual ones" (2007, 211). Migeon proposes that "cellular mosaicism . . . is likely to contribute to some of the gender differences in behavior" (209), including females' response to humor and differences in aggression, emotionality, and educational performance between males and females (2006, 1432–33). Molecular research on X chromosome mosaicism, Migeon argues, offers a promising platform for uncovering sex differences in the brain that studies of brain anatomy have not, thus far, revealed: "Despite dramatically different behavior between the sexes, surprisingly few anatomical differences have been identified," she writes, "[Perhaps] mosaicism for X-linked genes . . . may contribute to some of these sex differences in behavior" (2007, 211).

These speculative scientific conceptions of X mosaicism and femaleness are present in popular discourse around gender differences. Science reporter Natalie Angier, in *Woman: An Intimate Geography* (1999), celebrates female X chromosome mosaicism as a privilege of womanhood and a source of special womanly qualities. "Every daughter," she writes, "is a walking mosaic of clamorous and quiet chromosomes, of fatherly sermons and maternal advice, while every son has but his mother's voice to guide him" (25). She posits what she calls "the mystical X" as a source of "female intuition" and asserts that women "have . . . with the mosaicism of our chromosomes, a potential for considerable brain complexity" (25). Angier imagines a woman's X chromosomes as animating her brain with conflicting voices: "a woman's mind is truly a syncopated pulse of mother and father voices, each speaking through whichever X, maternal or paternal, happens to be active in a given brain cell" (25).

Female X mosaicism is also invoked to bring the authoritative veneer of molecular science to traditional and pejorative views of femininity. Bainbridge's *The X in Sex: How the X Chromosome Controls Our Lives* (2003), for instance, asserts that X chromosome mosaicism confirms that "women are mixed creatures and men are not . . . in a way far deeper" than previously thought (130). Citing the roots of this notion in the Christian vision of Mary as "both virgin and mother" (129), Bainbridge claims that women "represent some intermediate hybrid state" (128), revealed in their "unpredictable, capricious nature" (127). X mosaicism is a "natural reminder of just how deeply ingrained the mixed nature of women actually is" (148), writes Bainbridge. He continues: "So women's bodies truly are mixed—in a very real way. . . . Each woman is one creature and yet two intermingled" (151).

CASE STUDY: X MOSAICISM THEORIES OF FEMALE AUTOIMMUNITY

The case of X mosaicism theories of female autoimmunity shows clearly how contemporary biomedicine continues to find resources in the mercurial links between the X chromosome and femaleness. Autoimmune disorders are more prevalent in women than men.[9] The current medical model holds that autoimmunity occurs when the immune system misrecognizes the body's own tissues as invaders, leading the system, finely tuned to eliminate foreign agents, to continually attack the body's tissues with all of its resources. Some researchers, noting the female prevalence of autoimmune diseases and seeing a parallel between the self-on-self attacks of autoimmunity and mosaic female tissues made up of cells expressing the maternal or paternal X chromosome, have sought a mechanism for autoimmunity in X mosaicism. These theories draw on the notion that the X chromosome mediates female biology and health, as well as gender-inscribed conceptions of the female body as fundamentally chimeric, to link female autoimmunity to X mosaicism.[10]

The most basic version of the X mosaicism hypothesis of female autoimmunity is that simple mosaicism of the X chromosome, in cases in which the X produces two conflicting immune products, leads to autoimmunity. There is also a more sophisticated version, which holds that if mosaicism is skewed so that an immunologically relevant organ, such as the thymus gland, contains a majority of one X, the immune system may misrecognize tissues that carry the other X, leading to an autoimmune reaction (Kast 1977; Stewart 1998). Evidence for X mosaicism hypotheses of female autoimmunity has been sought in studies of skewed X mosaicism in women with autoimmune disorders. In these studies, researchers look at the percentage of cells carrying the maternal or paternal X chromosome (typically in a blood sample). When one predominates, if it is above a threshold of either 80 or 90 percent, the woman is deemed to have skewed X mosaicism.

These studies provide little evidence that X mosaicism is implicated in female predominance in autoimmunity. A higher rate of skewed X mosaicism than the general population has been demonstrated in just two cases: scleroderma (Ozbalkan et al. 2005) and autoimmune thyroid disorders (Ozcelik et al. 2006). It has not been found in the cases of lupus (Invernizzi et al. 2007), multiple sclerosis (Accelerated Cure Project 2006; Knudsen et al. 2007; Knudsen 2009), type 1 diabetes (Chitnis et al. 2000), or juvenile rheumatoid arthritis (Seldin et al. 1999), nor has it been found in the female-predominant and potentially autoimmune disorders of simple goiter (Brix et al. 2009) and recurrent pregnancy loss (Pasquier et al. 2007). There is conflicting, weak, or ambiguous evidence of an association with skewed X mosaicism in the case of primary biliary cirrhosis (Invernizzi 2007; Svyryd et al. 2010) and adult onset rheumatoid arthritis (Svyryd et al. 2010).

Even if studies were to document high rates of X skewing in women with certain autoimmune disorders, this would not, in any case, constitute sufficient evidence that skewed X mosaicism predisposes women to those disorders or that women are more inclined, in general, to autoimmunity. First, almost all X mosaicism studies use blood samples, looking at peripheral lymphocytes rather than cell types within the immune reaction pathways or organ systems of interest. This limits their significance. For example, women with the skin disease scleroderma show skewed mosaicism in their blood, but this skewing was not also found in the skin cells—the tissue of interest for the disorder in question. Second, these studies do not rigorously account for the confounding effect of age. Rates of both autoimmunity and X skewing increase with age in women (Russell et al. 2007), and to date studies of X mosaicism pattern variation do not persuasively disambiguate aging and autoimmunity.[11] Third, the X mosaicism hypothesis does not explain enough specific features of female predominance in autoimmunity to stand as a candidate for an explanation of the greater prevalence of autoimmunity in females. For example, the theory cannot explain the following: why the incidence of autoimmunity, but not the severity of the disease, differs between males and females; why female predominance is much more pronounced among the cohort diagnosed with autoimmune disorders under age 40, with rates becoming more equal between the sexes as they age; why some autoimmune disorders are female predominant, some are male predominant, and others are sex neutral; how X mosaicism interacts with the significant and well-documented role of environmental factors involved in sex differences in autoimmunity (such as chemicals in cosmetics or the workplace); and finally, why there is wide variability in sex ratios of autoimmune diseases between different ethnicities, nations, and in developed versus less-developed regions of the world (see Lockshin 2006, 2010; Oliver and Silman 2009).

In sum, although research is ongoing, the evidence for the X mosaicism hypothesis of female autoimmunity is weak. Degree of X skewing has not been found to be a predictive biomarker of autoimmunity, nor of response to therapy, and it has not been demonstratively linked to autoimmunity in animal models or in humans. Yet researchers confidently assert that X mosaicism mediates female autoimmunity: “autoimmune diseases revolve around the sex chromosomes," writes Carlo Selmi (2008, 913). Zoltan Spolarics (2007) claims that "X-chromosome mosaicism represents an adaptive cellular system" (599) bestowing females with "potentially two distinct regulatory and response arsenals" (598) and predisposing them to autoimmunity.

Such assertions by biomedical researchers that the XX chromosome complement inclines women to autoimmunity are clearly unwarranted. Studies of associations between X mosaicism patterns and autoimmunity do not substantiate a causal link between the two phenomena, nor do they show precisely how the presence of two populations of cells might contribute to autoimmune reactions. The evidence suggests, rather, that X mosaicism is far from a general theory of, or a major factor in, higher rates of autoimmune disorders in females.

The notion that X mosaicism underlies female autoimmunity has become so commonplace that it now regularly appears as authoritative medical knowledge in health news reports and is considered a leading viable hypothesis in much of the literature on autoimmunity.[12] The immediate credibility given by molecular biologists to X mosaicism theories of female autoimmunity, and the theory's widespread uncritical repetition in a variety of research, clinical, and health media contexts, requires explanation given the theory's weak empirical basis. The credulous reception of the theory is driven in part by the stubborn and commonplace belief, documented in this essay, that the gender binary of male and female is present, writ molecular, in the sex chromosomes. Just as the Y is putatively the male chromosome, the X chromosome must, it is assumed, be a fundamental mediator of femaleness. Rooted in notions of the X as female, and chimerism as feminine, X mosaicism theories of female autoimmunity, I argue, present a contemporary case of synecdochic gendered conceptions of sex in biology leading to flawed scientific reasoning.

CONCLUSION

Currently, there is a broad popular, scientific, and medical conception of the X chromosome as the mediator of the differences between males and females, as the carrier of female-specific traits, or otherwise as a substrate of femaleness. As this essay has documented, associations between the X and femaleness are the accumulated product of contingent historical and material processes and events, and they are inflected by beliefs rooted in gender ideology. The still very contemporary view that the double X makes females unpredictable, mysterious, chimeric, and conservative, while the single X allows men to learn, evolve, and have bigger brains but also makes them the more risk taking of the two sexes, shows how conceptions of X chromosome structure and function often reflect and support traditional gender stereotypes.

In light of the empirical and conceptual weaknesses of these theories, scientists must work to develop alternative models of the relationship between the X and sex. They must cultivate an active practice of gender criticality, exposing their theories to rigorous examination from all perspectives. While the presence of a single X in males and a double X in females does have different implications for male and female biology, historical and contemporary speculations over the relation between the X and femaleness show that this assumption has consistently contributed to erroneous biological reasoning and that the X has been overburdened with explaining female biology and sex differences. As this essay has shown, the X chromosome has not only become female identified as an object of biological research, but has, more broadly, become a highly gendered screen upon which cultural theories of sex and gender difference have been projected throughout the twentieth century and up to the present day. The case of how the X became the female chromosome presents a prominent example of how unquestioned gender assumptions can distort and mislead, not only within the biological sciences but more generally in the production of knowledge.

NOTES

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1. Seema Kuman, "Genes for Early Sperm Production Found to Reside on X Chromosome," Massachusetts Institute of Technology press release, April 4, 2001. http://web.mit.edu/newsoffice/2001/sperm-0404.
2. See, e.g., Burgoyne (1998), Angier (1999, 2007), Graves (2000), and Bainbridge (2003).
3. See *Slate*'s "The XX Factor: What Women Really Think" blog at http://www.slate.com/blogs/xx_factor.html.
4. Berman's assertion that females possess "two more chromosomes" reflects the understanding of female-determining gametes as carrying an "extra" X chromosome. If females receive an extra chromosome from each parent, then in the full chromosome complement, females would be expected to have two more chromosomes than males.
5. While it is certainly true that a second X shields females from many X-linked diseases, the presence of "extra" genetic material cannot be said to establish any of these claims to female superiority. After all, chimpanzees and corn have more DNA than humans.
6. See also Miller (2006) on the deliberations over the true gender of Turner and Klinefelter individuals in the decade after the discovery of the Barr body.
7. In biology, a genetic mosaic is distinct from a genetic chimera. Mosaics carry two different types of cells, whereas chimeras are made up of fused cells of two individuals or species. "Mosaic" and "chimera" are used interchangeably and with the same connotations in the literature on X mosaicism, however, and I follow suit here.
8. Lederberg also notes, however, that the case of XXY males "complicates the myth that chimerism is femininity" (1966, E7).
9. For statistics on male and female incidence and prevalence of autoimmune diseases, see Jacobson et al. (1997), Walsh and Rau (2000), Lockshin (2006), Eaton et al. (2007), Cooper, Bynum, and Somers (2009), and McCombe, Greer, and Mackay (2009).
10. Feminist science studies scholars Donna Haraway (1991), Emily Martin (1999), and Lisa H. Weasel (2001) are among those who have explored the relationship between immunity discourse and gendered metaphors and imagery, unpacking the parallels between "horror autotoxis" (medical researcher Paul Ehrlich's 1957 term for autoimmunity) and traditional conceptions of femininity. As Martin (1999) notes, the greater susceptibility of females to autoimmune disease, leading to suggestions that females are biologically "hybrid" (101) and "mixed-up" (103), aligns with ideological notions of females as double, divided against themselves, contradictory, unstable, and lacking in unitary selfhood.
11. The background picture of diversity of X mosaicism patterns in the general female population is also, on the whole, not well understood. James Amos-Landgraf et al. (2006), in the most credible study of its kind, looked at patterns in 1,005 phenotypically unaffected females, finding that skewing was relatively common. The study reported that fully 25 percent of females had patterns skewed at least to 70:30 and concluded that "with advancing age, there is greater variation in X inactivation-ratio distribution" (497).
12. See, e.g., *Nature Genetics* (2000), Kruszelnicki (2004), Davies (2005), McCoy (2009), and Tingen (2009).

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SECTION IV

Thinking Theoretically

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CHAPTER 21

Rethinking Cyberfeminism(s): Race, Gender, and Embodiment

Jessie Daniels

"If you can't slap him, snap him," is the tag line for the website HollaBackNYC (http://www.hollabacknyc.com). The site's creators, fed up with everyday harassment by men exposing themselves on New York's streets and subways, encourage women to use their Internet-enabled cell phones to snap photos of harassers and upload them to the site. This ingenious use of technology is emblematic of an array of new expression of feminist practices called "cyberfeminism." Among cyberfeminists (Orgad 2005; Plant 1997; Podlas 2000), some have suggested that Internet technologies can be an effective medium for resisting repressive gender regimes and enacting equality, while others have called into question such claims (Gaijala 2003). Central to such claims and counterclaims about the subversive potential of Internet technologies is theorizing that constructs women of color as quintessential cyborgs (Fernandez 2002, 32), as when Haraway writes about the "cyborg women making chips in Asia and spiral dancing in Santa Rita" (1985, 7). In this essay, I offer an overview of cyberfeminist theories and practices. Drawing on a wide array of theoretical literature and empirical research, I review cyberfeminist claims about the subversive potential of human/machine cyborgs, identity tourism, and disembodiment within a global networked economy alongside analyses that highlight the lived experience and actual Internet practices of girls and self-identified women.[1] While some cyberfeminists contend that the Internet shifts gender and racial regimes of power through the human/machine hybridity of cyborgs (Haraway 1985), identity tourism (Nakamura 2002; Turkle 1997), and the escape from embodiment (Hansen 2006; Nouraie-Simone 2005b), I argue that the lived experience and actual Internet practices of girls and self-identified women reveals ways that they use the Internet to transform their material, corporeal lives in a number of complex ways that both resist and reinforce hierarchies of gender and race.

While drawing on academic disciplines, I also focus rather deliberately on the theoretically informed empirical investigations by sociologists into Internet practices. Saskia Sassen's work addresses the embeddedness of the digital in the physical, material world, and she catalogs the ways that digital technologies "enable women to engage in new forms of contestation and in proactive endeavors in multiple different realms, from political to economic" (2002, 368). In contrast, Lori Kendall (1996, 1998, 2000, 2002), in her richly nuanced ethnography of the gendered dynamics in the multiuser domain (MUD) BlueSky, argues that digital technologies reproduce rather than subvert white, heterosexual, masculine cultures and hierarchies of power. In a 1997 article "Changing the Subject," Jodi O'Brien writes eloquently about the strict policing of gender identity online and the limitations of identity tourism. And Victoria Pitts's (2004) research about women's use of the Internet on breast cancer forums offers an important corrective to the discourse about disembodiment popular in cyberfeminist writing. My focus is based at least partly on familiarity; I am a sociologist by background and training, so it is the field in which I am most conversant. Focusing on empirical sociological research about Internet practices is also an effective strategy for informing theoretical claims about the subversive potential of digital technologies. Finally, my focus on sociological research is meant to serve as a challenge to those who claim to want to transform as well as inform society yet have little engagement in the cyberfield.

BEYOND "ZEROES AND ONES": GENDER, RACE, AND CYBERFEMINISM(S)

Cyberfeminism is neither a single theory nor a feminist movement with a clearly articulated political agenda. Rather, "cyberfeminism" refers to a range of theories, debates, and practices about the relationship between gender and digital culture (Flanagan and Booth 2002, 12), so it is perhaps more accurate to refer to the plural, "cyberfeminism(s)."Within and among cyberfeminism(s) there are a number of distinct theoretical and political stances in relation to Internet technology and gender as well as a notice able ambivalence about a unified feminist political project (Chatterjee 2002, 199). Further, some distinguish between the "old" cyberfeminism, characterized by a utopian vision of a postcorporeal woman corrupting patriarchy, and a "new" cyberfeminism, which is more about "confronting the top down from the bottom-up" (Fernandez, Wilding, and Wright 2003, 22–23). Thus, any attempt to write about cyberfeminism as if it were a monolith inevitably results in a narrative that is inaccurately totalizing. However, what provides common ground among these variants of cyberfeminism(s) is the sustained focus on gender and digital technologies and on cyberfeminist practices (Flanagan and Booth 2002, 12; Chatteijee 2002, 199; Fernandez, Wilding, and Wright 2003, 9–13).

Cyberfeminist practices involve experimentation and engagement with various Internet technologies by self-identified women across several domains, including work (Scott-Dixon 2004; Shih 2006), education (Clegg 2001), domestic life (Na 2001; Ribak 2001; Singh 2003), civic engagement (Harcourt 2000), feminist political organizing (Everett 2007; Sutton and Pollock 2000), art (Fernandez, Wilding, and Wright 2003), and play (Bury 2005; Cassell and Jenkins 2000; Flanagan 2002; Kendall 1996).While there is no consistent feminist political project associated with cyberfeminist practices, within a culture in which Internet technology is so pervasively coded as "masculine" (Adam 2004; Kendall 2000), there is something at least potentially transgressive in such practices (Fernandez, Wilding, and Wright 2003).

Rosalind Gill takes exception to the notion that there is anything subversive in these practices when she describes "women's depressingly familiar . . . use of the Internet in affluent northern countries . . . primarily for e-mail, home shopping and the acquisition of health information" (2005, 99; see also Herring 2004). Indeed, the commercialization of the Internet at sites such as iVillage.com ("the Internet for women") co-opts the rhetoric of feminism for profit (Royal 2005), as does much of the health information online (Pitts 2004). While it is true that many affluent women in the global North have "depressingly familiar" practices when it comes to the Internet, this sort of sweeping generalization suggests a lack of awareness about the innovative ways women are using digital technologies to re-engineer their lives.[2]

Sue Rosser, in her expansive review of information technology through different feminist lenses, concludes that although cyberfeminism uses "aspects of different feminist theories," it lacks a sufficiently coherent framework to be characterized as anything but a "developing feminist theory" (Rosser 2005, 19).[3] Other scholars writing about cyberfeminism(s) are less concerned with the lack of a coherent framework and, indeed, revel in the "sporadic, tactical, contradictory set of theories, debates and practices" (Booth and Flanagan 2002, 12) that constitute cyberfeminism(s). Yet it is exceedingly rare within both cyberfeminist practices and critiques of them to see any reference to the intersection of gender and race (Fernandez, Wilding, and Wright 2003, 21); instead both the practices and the critiques suggest that "gender" is a unified category and, by implication, that digital technologies mean the same thing to all women across differences of race, class, sexuality.

In her book *Zeroes and Ones,* Sadie Plant is exuberant about the potential of Internet technologies to transform the lives of women. Plant conceptualizes cyberspace as a liberating place for women because, as she sees it, the inherently textual nature of the Internet lends itself to "the female" (1997, 23). Her title refers to the binary code of zeroes and ones that constitutes the basic programming language that computers use. Plant symbolically renders zeroes as "female" and ones as phallic and "male," predicting that the digital future is feminine, distributed, nonlinear, a world in which "zeroes" are displacing the phallic order of the "ones" (Gill 2005, 99). Plant is perhaps the leading figure in popularizing the ideas of cyberfeminism beyond the academy. While Plant has been justifiably criticized for reinscribing essentialist notions of gender (Wilding 1998), Wajcman (2004) writes that Plant's optimism about the potential of gender equality in cyberspace must be understood as a reaction against previous conceptualizations of technology as inherently masculine. In addition to essentializing gender, Plant's binary of "zeroes" and "ones" leaves no conceptual room for understanding how gen der intersects with "race." In this way, Plant's writing is characteristic of the field, as there is relatively little discussion of the intersections of gender with "race," except in cases where "race" is included in a long list of additional variables to be added on to "gender." Thus, when cyberfeminists explicitly engage both gender and race it is both conspicuous and instructive.

In their edited volume, *Domain Errors! Cyberfeminist Practices,* Fernandez, Wilding, and Wright highlight cyberfeminist practices that eschew the exclusionary aspects of earlier forms of feminism, and they remind us "the lives of white women and women of color are mutually reliant" (2003, 25). Yet, as Fernandez and Wilding point out, cyberfeminist writing often assumes an "educated, white, upper-middle-class, English-speaking, culturally sophisticated readership," which ironically ends up replicating the "damaging universalism of 'old-style feminism' " (Fernandez and Wilding 2003, 21). Given the "damaging universalism" of some forms of cyberfeminism, what, then, do we make of claims for the subversive potential of the Internet?

In the following two sections, I explore the evidence for the view that the Internet is a technology that facilitates gender and racial equality. First, I focus on questions related to political economy and internetworked global feminism. Then, I turn to debates about "identity tourism" and the allure of disembodiment by contrasting examples of the way girls and women are using the Internet to transform their bodies.

"A LIBERATING TERRITORY OF ONE'S OWN": POLITICAL ECONOMY AND INTERNETWORKED GLOBAL FEMINISM

A central debate within cyberfeminism has to do with the tension between the political economy required to mass produce the infrastructure of the Internet and its reliance on the exploited labor, on the one hand, and, on the other, claims for the subversive potential of those same technologies.

Easily the most influential figure in cyberfeminism is Donna Haraway. Her conceptualization of the *cyborg,* part human and part machine (1985), and the subversive potential of a cyborg future, are of particular interest to a number of scholars who come to gender and technology through poststructuralism and cyberpunk fiction (Balsamo 1996; Flanagan and Booth 2002; DeVoss 2000; Flanagan 2002; Sunden 2001; Wolmark 1999). In contrast to this promised future, critics have pointed to the problematic construction of women of color working in technology manufacturing as quintessential cyborgs (Flanagan and Booth 2002; 12). The low-skilled work in microchip production and global call centers has not eased "the oppression of Third World women, . . . [it] has merely perpetuated their oppression in a new workplace" (Flanagan and Booth 2002,13; see also Eisenstein 1998). Radhika Gajjala raises the central question about the possibility of "subaltern cyberfeminism from below," given this economic context: "If cyberspace is produced at the expense of millions of men and women all over the world who are not even able to enjoy its conveniences, how can we make claims that [these technologies] are changing the world for the better?" (2003, 49). This juxtaposition of subversive Internet technologies, on the one hand, and global economic inequality, on the other, is one that few scholars writing about cyberculture acknowledge. Yet, in rethinking cyberfeminism, it is crucial to examine both. In the following section, I take up the empirical evidence about political economy, gender, and race.

Political Economy

To take a global perspective, it is clear that those in industrialized nations are more likely to own computers and have Internet access than are those in developing societies (Norris 2001). The material reality of the global political economy is that women remain the poorest global citizens; the digital era has not shifted this in significant ways (Eisenstein 1998). However, aggregate-level country-specific data show that women have increasing rates of participation online, often at faster rates than men (Sassen 2002, 376). It is not surprising that women lag behind men globally in computer use and Internet access, given that these are so clearly linked to economic resources (Bimber 2000; Leggon 2006; Norris 2001). What is intriguing is that despite women's place at the bottom of the global economic hierarchy, their Internet participation is rapidly increasing.

In the United States, the empirical research indicates that most of the apparent "digital divide" in computer ownership and Internet access, has been the effect of class (or socioeconomic status) more than of gender and race (Norris 2001). In the United States, the rate of Internet access has converged for men and women who are white (Leggon 2006, 100). There remain some small differences in access and kinds of usage between Hispanic women and men and between African American women and men; these differences, however, are negligible (Leggon 2006, 100). Yet despite the convergence and negligible differences across gender and race, public intellectuals such as Henry Louis Gates Jr. and Anthony Walton do not hesitate to assert that Black culture is "the problem" when it comes to the digital divide (Wright 2002, 2005). Discourse of "the digital divide" that configures "women" or "Blacks and Hispanics" or "the poor" living in the global South as information "have-nots" is a disabling rhetoric (Everett 2004, 1280) that fails to recognize the agency and technological contributions of African Americans, Asians, Chicanos, Latinos, and working-class whites (Wright 2002, 57). What we need is a more multidimensional view of inequality of access that allows for individual agency.

Conceptualizing digital technologies exclusively in terms of either economic oppression or lack of access is overdetermined and does not allow for women's agency with regard to the Internet. Gajjala recognizes this agency by pointing out that the very people who are excluded from mainstream society want to include themselves in these new technologies on their own terms so that "they can see themselves as protagonists of the revolution" (2003, 49). For many women, including themselves in these new technologies means including themselves in internetworked global feminism.

Internetworked Global Feminism

Within the context of a global political economy, internetworked global feminism can and does bypass national states, local opposition, mass media indifference, and major national economic actors, thus opening a whole new terrain for activism that addresses gender and racial inequality (Sassen 2002; Earl and Schussman 2003; Everett 2004; Kahn and Kellner 2004; Langman 2005; Sutton and Pollock 2000).

For women of color who want to connect globally across diasporas what Chela Sandoval refers to as "U.S. third world feminism" (2000)—the cyberfeminist practice of online organizing and discursive space takes on added significance. Gajjala's (2003, 2004) writing about South Asian diasporas online is a case in point. Her work combines critical, theoretical analysis with years of hands-on practice building e-spaces, such as SAWnet, the women-only South Asian Listserv. Gajjala points out that if cyberfeminist agendas are to "produce subversive countercultures or to succeed in changing existing technological environments so that they are empowering to women and men of lesser material and socio-cultural privilege the world over, it is important to examine how individuals and communities are situated" within the global political economy (2003, 54). For women of color who have been systematically excluded from mainstream civic engagement on the basis of race and gender, the political online organizing of African American women both in the United States and globally around the Million Woman March provides another example of cyberfeminism. As Anna Everett writes: "The sistahs of the march recognized the value of new technologies to further their own agendas and to promote their brand of activism, which did not require choosing which liberation struggle to fight first, gender or race oppression" (2004, 1283).

In a similar vein, Michelle Wright notes the cyberfeminist practice of online communities designed specifically by and for Black women, such as SistahSpace (http://www.Sistahspace.com). Wright exhorts other women of color to engage with the "Internet beyond Web surfing and checking e-mail" (2005, 57). The kinds of cyberfeminist practices suggested by Gajjala, Everett, and Wright are more overtly political than other cyberfeminist practices and are part of what Sandoval (2000) refers to as an oppositional technology of power.

Many women in and out of global feminist political organizations view Internet technology as a crucial medium for movement toward gender equality (Cherny and Weise 1996; Harcourt 1999, 2000, 2004; Purweal 2004; Merithew 2004;Jacobs 2004). Wendy Harcourt, an Australian feminist researcher with the Society for International Development, a nongovernmental organization (NGO) based in Rome and the author of *Women@ Internet: Creating New Cultures in Cyberspace,* is a leading proponent of this view. She summarizes this stance when she writes that there is "convincing evidence that the Internet is a tool for creating a communicative space that when embedded in a political reality can be an empowering mechanism for women" (1999, 219). The notion that the Internet is a "tool" to be picked up and "used" by women for "empowerment" is a metaphor that is employed repeatedly in the literature about global feminist organizations and the Internet. The evidence to which Harcourt refers is written primarily by women working in NGOs that focus on gender equality in their local regions and globally, a focus some have referred to as "glocality" (1999). The mobilization of global awareness and opposition to the repressive Taliban regime by the Revolutionary Association of Women of Afghanistan (http:/*I* www.rawa.org) is just one example of the effective use of the Internet by a global feminist organization (Kensinger 2003). Another example comes from Mexico, where a number of feminist NGOs have used the Internet in their efforts to cross national frontiers to establish a system of global support and exchange in pursuit of a more gender-equitable society (Merithew 2004). And global feminist networks begun in South Asia have fostered a challenge to gender-specific abortion, or "son selection," as some refer to the practice of terminating pregnancies in which the fetus is female (Purweal 2004). Lauren Langman (2005) refers to these kinds of global social movements organized online as internetworked social movements, or ISMs. These organizations, and the women writing from within them, make a strong case that information technology facilitates transnational feminist networks and indicate a measure of success for global feminism Qacobs 2004). Sassen enumerates dozens of women's organizations online and argues that women's presence in and use of the Internet has the potential to transform a whole range of local conditions and institutional domains where women are key actors (2002, 379).

Many individual women outside any formal political organization experience the Internet as a "safe space" for resisting the gender oppression that they encounter in their day-to-day lives offline. In her edited volume *On Shifting Ground: Muslim Women in the Global Era,* Fereshteh Nouraie Simone (2005a) includes essays about the importance of global information technology for women living in and resisting repressive gender regimes. Nouraie-Simone's description of the importance of the Internet is noteworthy: "For educated young Iranian women, cyberspace is a liberating territory of one's own—a place to resist a traditionally imposed subordinate identity while providing a break from pervasive Islamic restrictions in public physical space. The virtual nature of the Internet—the structure of interconnection in cyberspace that draws participants into ongoing discourses on issues of feminism, patriarchy, and gender politics, and the textual process of self-expression without the prohibition or limitation of physical space—offers new possibilities for women's agency and empowerment" (2005b, 61–62).

Here, Nouraie-Simone evokes Virginia Woolf's call for a "room of one's own" as a prerequisite for feminist consciousness when she describes her experience online as a "liberating territory of one's own." Rather than the "tool" imagery invoked by so many of the global feminist organizations when describing information technology, Nouraie-Simone chooses the term "cyberspace" to suggest that she goes to a "place to resist," where she participates in discussions of "feminism, patriarchy, and gender politics." For her, cyberspace makes global feminism possible in her life offline on an intimate, immediate, and personal level.

While the evidence presented here about the political economy and global feminist organizations and individuals using Internet technologies in ways that resist oppressive regimes of gender and sexuality is admittedly anecdotal, it does offer some insight into the questions, Is the Internet subversive? If so, for whom? Sassen's concept of embeddedness, that is the Internet as embedded in materiality, is useful here. As Sassen notes, there is no "purely digital" or exclusively "virtual" electronic space; rather, the digital is always "embedded" in the material (2002, 367–68). Melanie Millar (1998) calls attention to the uneven effects of digital technologies on diverse groups of women. For the women working in a microchip factory in China or a call center in India, the Internet is not a subversive potential future but a work place rooted in economic necessity. For women in global feminist organizations outside the affluent global North, the Internet is a "tool" to be used for addressing gender inequality in local regions and leveraging connections to feminists in other regions. For Nouraie-Simone, the Internet is a "safe space" to occupy away from a repressive gender regime in the offline world. Each has different relations to digital technologies, and these are embedded in present-tense, material, embodied lives rather than imagined cyborg futures.

THE ALLURE OF IDENTITY TOURISM AND DISEMBODIMENT

After the cyborg, the two ideas that hold the most allure for cyberfeminists interested in the subversive potential of the Internet are identity tourism and disembodiment. Lisa Nakamura in her book *Cybertypes* coins the term "identity tourism" to describe "the process by which members of one group try on for size the descriptors generally applied to persons of another race or gender" (2002, 8). The allure of changing identities online has been part of the sociological writing about the Internet since Sherry Turkle's *Life on the Screen*. Turkle contends that assuming alternate identities online can have positive psychological and social effects by loosening repressive boundaries (1997, 12; see also Westfall 2000; Whitley 1997). The idea that racial oppression is linked to embodied visibility is one about which African American sociologists and other scholars have written eloquently, going back to W. E. B. Du Bois (Du Bois 1903/1995; Tal 2001).This idea appears frequently in mainstream press accounts as well as the scholarly literature on "race" and the Internet, as in this passage from Mark Hansen: "The suspension of the social category of visibility in online environments transforms the experience of race in what is, potentially a fundamental way: by suspending the automatic ascription of racial signifiers according to visible traits, online environments can, in a certain sense, be said to subject everyone to what I shall call a 'zero degree' of racial difference" (2006, 141).

However, changing identities online may not be as subversive an experience as Turkle and others suggest. Jodi O'Brien notes that gender-switching online is only acceptable within very narrow boundaries and that there is an "earnestness with which gender-policing is conducted" when gender switching occurs (1999, 82).[4] O'Brien interprets the earnest "gender policing" to mean that when it is intended as play or performance, switching identities is tolerated as long as there is agreement that a "natural" (read physical/biological) referent remains "intact, embodied and immutable" (O'Brien

1999, 82). Switching identities online seems much less prevalent than the kinds of online experiences that Pitts describes in her research on women with breast cancer who seek and find real community and create new forms of knowledge via sites such as Women.com's BreastFest (Pitts 2004, 55).

Additional research into actual online practices suggests that rather than going online to "switch" gender or racial identities, people actively seek out online spaces that affirm and solidify social identities along axes of race, gender, and sexuality. For example, young girls and teens who have access to the Internet increasingly form their identities, at least in part, through their online interactions (Mazzarella 2005), often via social networking sites such as MySpace or Facebook (boyd 2004); people of color affirm racial identities online through BlackPlanet.com, MiGente, and AsianAvenue.com (Byrne 2007; Lee and Wong 2003); and self-identified QLBT (queer, lesbian, bisexual, and transgender) women go online to "learn to be queer" (Bryson 2004, 251) by using sites such as QueerSisters (Nip 2004; see also Alexander 2002). In large measure, the notion of "identity tourism," in which people switch gender and racial identities, functions as a heuristic device for thinking about gender and race rather than this activity being a commonplace online practice. What then of the cyberfeminist claim of dispensing with embodiment as a path to gender (and racial) equality?

Nouraie-Simone writes that part of *why* she finds the Internet so subversive while living under a repressive sex/gender regime in Iran is the chance to escape embodiment: "The *absence of the physical body* in electronic space and the anonymity this offers have a liberating effect on repressed social identity, as 'electronic technology' becomes 'a tool for the design of freely chosen identities' " (2005b, 61–62; emphasis added). In this passage, she connects liberation from gender oppression to the absence of the body as well as to the ability to adopt "freely chosen identities." While it is not clear from Nouraie-Simone's writing if her practice includes "switching" gender or ethnic identities, it seems unlikely, given that in this same passage she writes that she goes online to seek out "discourse" on "issues of feminism, patriarchy, and gender politics," as part of her "self-expression" (2005b, 61–62).The impact of digital technologies on self-identified women's lives is grounded in materiality and embodiment. Pitts is instructive on this point: "Online women with breast cancer are not necessarily interested in gender-play or too interested in leaving the body behind them. Their public narratives do not 'hide' the body, and they generally do not abandon gender, beauty and conventional femininity. . . . In detailing some of the more unpleasant bodily aspects of sickness and treatment, they present women's bodies as they are really lived" (2004, 55).

Instead of going online to escape embodiment, the women in Pitts's study seek out Internet spaces where they can explore and reaffirm the bodily selves in the presence of illness, surgery, recovery, and loss. Pitts's research is useful for considering the impact of the Internet on self-identified women's lives and illustrates the ways women engage with Internet technologies in order to create meaning for themselves to improve, or at least change, the material conditions of their lives and their bodies.

The putative invisibility online and the "decoupling identity from any analogical relation to the visible body" (Hansen 2006, 145) to escape race and gender visibility rests on an assumption of an exclusively text-based online world that belies the reality of digital video and photographic technologies, such as webcams (and image-sharing sites, among them

Flickr and YouTube), which make images of bodies a quotidian part of the gendered, and racialized, online world (White 2003). Rather than a libertarian utopia of disembodiment, cyberspace must be considered an environment in which "definitions of situation, body, and identity are both contested and are influenced by power relations" (Pitts 2004, 53–54). The allure of disembodiment for many cyberfeminists alongside the valorization of self-identified women and girls' engagement with Internet technologies suggests an inherent contradiction within cyberfeminism. The use of Internet technologies to (re)shape bodies by the seemingly disparate communities of "pro-ana" girls discussed below and transgendered women illustrates this contradiction.

THE CONTINUING SIGNIFICANCE OF EMBODIMENT: "PRO-ANA" WEBSITES AND "TRANNY" HORMONE LISTSERVS

Cyberfeminists have heralded the allure of disembodiment as a way to subvert gender and gender oppression. Some cyberfeminists, such as Braidotti (2002), Plant (1997), and Wilding and CA Ensemble (1998), recognize and celebrate the potential of a new wave of feminist practices that engage with Internet technologies in ways that chart new ground for women. However, foregrounding women and girls' engagement with Internet technologies suggests that there is something innately feminist in such practices. Wilding and other cyberfeminists (Everett 2004) have warned that the valorization of women's cyberpractices without an accompanying feminist critique is problematic. In the following section, I offer two examples that illustrate both the continuing significance of embodiment online and the problematic of uniformly regarding all women's engagement with cyberspace as feminist.

Pro-Ana Websites

The emergence of pro-ana, a shortened term for "pro-anorexia," sites suggests that some (mostly young, predominantly white) women form online communities in order to offer each other nonjudgmental support in finding strategies and tactics for disordered eating behaviors, most often diagnosed as anorexia nervosa or bulimia. These young women both resist and embrace such diagnoses for their behavior (Dias 2003; Fox, Ward, and O'Rourke 2005; Mulveen and Hepworth, 2006). As a young woman quoted in research by Fox, Ward, and O'Rourke put it, "Personally, I feel that if a person is starving themselves or throwing up *solely* because of the desire to look like kate moss, devon aoki (hehe . . . my favorite model), gisele, etc . . . they don't have all the criteria to be considered anorexic. Anorexia is defined as a mental disease . . . the ability to play mind-games with yourself relating to anything food or exercise" (2005, 955).

This redefinition of anorexia as "the ability to play mind-games" around food or exercise refigures the usually disabling rhetoric of eating disorders into one of strength and "ability" that does not include everyone who is "starving themselves." The mention of this young woman's "favorite model" is revealing here because famous models and celebrities are part of the cultural products that young women engaged in pro-ana seek out for "thinspiration" (954). The young girls of the pro-ana communities turn to the Internet to support their bodily rituals of diet, exercise, and purging in the relative "safety" of being with their pro-ana peers and away from the judgments of others (mostly parents) (Dias 2003; Fox, Ward, and O'Rourke 2005; Walstrom 2001).Young women who identify as pro-ana report that the bodily rituals associated with this community provide participants with a sense of "control over" their bodies (Dias 2003; Fox, Ward, and

O'Rourke 2005; Walstrom 2001). And increasingly, these images of "thinspiration" appear on YouTube, the video-sharing site, as well as on personal websites (Daniels and Meleo-Erwin 2008).Whatever one thinks of these practices, the young girls involved with pro-ana sites are engaging with Internet technologies in ways that are both motivated by and confirm (extremely thin) embodiment. While those participating in pro-ana sites may appear to be ambivalent about their own embodiment, the fact is that they are not going online to avoid corporeality but rather to engage with others *about* their bodies via text and image in ways that make them feel in control of those bodies.

"Tranny" Hormone Listservs

A second illustration of the way the Internet can be a site for bodily trans formation is that of community-based transgendered websites, such as GenderSanity (http://www.gendersanity.com), and personal web pages, such as Christine Beatty's WebHome (http://www.glamazon.net).These sites, along with Listservs and websites established by trans or trans-friendly physicians, such as TransGender Care (http://www.transgendercare.com), provide in formation about how to transform the body in specifically gendered ways. The experience of transgendered women, such as Anita, whose pastiche of Internet technologies enables her gender transition (Bryson 2004, 246), is noteworthy in this context. Many nonheteronormative or queer women, whether they identify as lesbian, bisexual, or transgender, also regard global information technology as an important medium for resisting repressive regimes of gender and sexuality (Alexander 2002; Bryson 2004; Chatterjee 2002; Heinz, Gu, and Zender 2002). Combining the metaphors of "tool" and "place," Mary Bryson, in her study of Australian QLBT women's experiences of the Internet, writes: "Internet tools and communities serve a variety of functions that are relevant to, and scaffold, the lives of QLBT women, including . . . interaction with other queer women in a space that is relatively safe" (2004, 249). Like Nouraie-Simone, the women in Bryson's study experience life online as a safe space, an observation that serves to set up an oppositional relationship to life offline ("real" life) as space that is not safe. The Internet provides QLBT women with opportunities to experiment with gender identity and practices, as well as a cultural context within which to learn how to be queer through participation in a subculture (Bryson 2004, 249). Indeed, the experience of Anita, included in Bryson's research, illustrates this point:

Anita: I've gotten a lot of information from the tranny hormone list. It was mainly an information sharing thing, and a few other lists along those lines. With the web, I've used transgendered sites for looking up reports of surgeons, photos of surgery, information from the surgeons here they'd posted that stuff up on the Net. Gaining information about hormones is important. I have a fair bit of experience in biochemistry and can read the scientific literature.

Mary: How do you access that information?

Anita: I can get into the MedLine database and that kind of thing. If I want information about any of that stuff, the Net is the first place I go. It's not always easy to find good information though, especially if you are looking for knowledge that is community-based. And if you are going to read the medical articles, you really need to know the jargon and be able to read between the lines. (2004, 246)

Here, Anita describes her use of the Internet to navigate the biomedical sex/ gender establishment (Butler 2004; Epstein 2003). She reports getting information from an e-mail Listserv, pursuing further information on particular surgeons, looking for digital photographic evidence of their work, and reading the peer-reviewed medical literature culled from the database MedLine. Both her technique for finding information and her assessment of what she finds demonstrate an example of sophisticated digital fluency (Green 2005, 2006). Anita's bricolage strategy combines a number of internet technologies, including search engines; web-based databases; websites dealing with transgender issues; community-based Listservs; and digital photography of surgical outcomes. Anita's goal in using a patchwork of digital technologies is not to pretend to be another gender online; instead, her aim is to find help in transforming her body *offline* in ways that align with her own sense of gender identity. Anita's piecing together of diverse Internet sources to navigate gender transition suggests that we need a much more nuanced and complex understanding of digital technologies, gender, and feminist politics.

Anita's experience indicates that rather than using the technology to escape embodiment or temporarily "switch" identities online, she and other self-identified women (and men) are actively engaging with digital technologies to more permanently transform their bodies offline. Anita goes on line not to experience "the absence of the body" (as Nouraie-Simone does) but to access the information, resources, and technologies that allow her to transform her body into a (differently) gendered body that aligns with her identity. And in ways that are analogous to the pro-ana girls' use of the technology, transgendered women, and men, use digital images as a crucial part of the strategy in gathering reliable information about gender transition.

Racialized Embodiment Online/Offline

The allure of disembodiment pointed to by cyberfeminists is understand able, given the significance of racialized embodiment (Du Bois 1903/1995; Fernandez 2003;Tal 2001) for understanding the lived experience of racism. Yet racialized embodiment and the ways this offline reality is embedded in online worlds is not often remarked upon in the literature about gender online.

In the study of pro-ana online communities by Fox, Ward, and O'Rourke (2005), the authors curiously do not take up racial identity as a point of analysis even when one of the participants explicitly references it: "It started in 8th grade. I had never been really overweight, but I was average-about 115 at 5'3. [T]here was just too much going on in my life . . . mostly, I didn't know who I was maybe I was having a really early mid-life crisis. I'm adopted, and my whole family is white, while I'm Asian. I had/have a lot of issues circling around feelings of abandonment which I partially translated into 'no one loves me . . . not even my real parents' type stuff" (957).

The young girl quoted here indicates that her racial identity, and the discordant racial identity of her (adopted) family, is a contributing factor in her desire to be involved with pro-ana practices. Yet the authors do not address the issue of racial identity. This is a lost opportunity for an analysis that would further illuminate the connection between gender, race, and online identity by speaking to the compelling research that exists involving gender, "race," and disordered eating (Lovejoy 2001; Thompson 1992).

In contrast, Bryson acknowledges the racial dynamics at work even though in her research her sample of QLBT women includes only one woman of color. The white participants in her study rarely identified racism as a problem of online communities, whereas "the discursive construction of racial identity online was a persistent problem for the Aboriginal participant whose Net experiences were frequently characterized by marginalization, silencing and enforced segregation" (2004, 246). The marginalization, silencing, and enforced segregation that the Aboriginal woman in Bryson's study faces in online spaces is characteristic of what many experience in online communities across lines of difference. Kendall's ethnography on the online community BlueSky is informative on this point. While BlueSky is relatively inclusive, and certainly not "racist" (or "sexist") in any overt way, the inclusive ness is predicated on social structure in which "white middle-class men continue to have the power to include or not to include people whose gender, sexuality or race marks them as other" (Kendall 2000, 272). BlueSky's text only nature facilitates greater inclusiveness across differences of gender, sexual orientation, and race, yet the predominance of white men simultaneously "limits the inclusiveness to 'others' who can fit themselves into a culture by and for those white men" (272). BlueSky, like the queer online spaces that the QLBT women in Bryson's study seek out and the pro-ana spaces that many young girls find empowering, are predicated on an assumption of whiteness. Unlike either the cyberracism of white supremacists online (Daniels 2009) or the white, masculine desire for community expressed by neoconfederates on Dixie-Net (McPherson 2000), the whiteness that Kendall describes in BlueSky is very much like whiteness in the offline world: an unmarked category that is taken for granted in daily life. Race matters in cyberspace precisely because "computer networks are social networks" (Wellman 2001) and those who spend time online bring their own knowledge, experiences, and values with them when they log on (Kolko, Nakamura, and Rodman 2000, 5). The fact that race matters online, as it does offline, counters the oft-repeated assertion that cyberspace is a disembodied realm where gendered and racialized bodies can be left behind.

These two examples, the pro-ana and transgendered online communities, shed light on gender, race, and the subversive potential of the Internet. In both instances, self-identified girls and women engage in practices with Internet technologies to manage, transform, and control their physical bodies in ways that both resist and reinforce hierarchies of gender and race. Instead of seeing cyberspace as a place in which to experience the absence of the body, or even a text-only place with no visible representation of the body, these girls and self-identified women use digital technologies in ways that simultaneously bring the body "online" (through digital photos uploaded to the web) and take the digital "offline" (through information gleaned online to transform their embodied selves). Here, digital technologies embedded in everyday life allow for the transformation of corporeal and material lives in ways that both resist and reinforce structures of gender and race.

CONCLUSION

This review of different forms of cyberfeminism(s) suggests a reality in which the Internet is embedded in material, corporeal lives in complex ways. To return to the illustrative example that opened the essay, the cyberfeminists who created HollaBackNYC are engaged with technologies in ways that highlight race, gender, and embodiment in the digital era. Mobile phone technologies, even in the current political economy, are widely affordable and extremely popular globally (Rheingold 2006). The tag line "If you can't slap him, snap him," suggests both the resistance of internetworked global feminism and a strategy of resistance that is simultaneously embedded in daily life, digital technologies, and embodiment. In this instance, to "hollaback" means to oppose an embodied notion of harassment (men exposing their genitals) with an embodied, and embedded, form of resistance (taking digital photos of those exposed bodies). However, given that the resisters pictured on the site are exclusively white and predominantly female, we must ask whether HollaBackNYC and its many imitators are disrupting or reinforcing the culture of surveillance focused on minority men in urban areas. Internet technologies offer women who are harassed on city streets and subways a mechanism for resisting such a gendered and racialized practices, at the same time that they reinforce established hierarchies of gender and race.

While some cyberfeminists are wildly enthusiastic about the subversive potential of a cyborg future, identity tourism, and disembodiment that is offered by digital technologies, evidence from cyberfeminist practices and empirical research on what people are actually doing online points to a more complicated reality. For son1e, the Internet economy reproduces oppressive workplace hierarchies that are rooted in a global political economy. For others, the Internet represents a "tool" for global feminist organizing and an opportunity to be protagonists in their own revolution. For still others, the Internet offers a "safe space" and a way to not just survive, but also resist, repressive sex/ gender regimes. Girls and self-identified women are engaging with Internet technologies in ways that enable them to transform their embodied selves, not escape embodiment. Girls involved in pro-ana com munities deploy Internet technologies that include text and images in order to control their bodies in ways that are both disturbing for others and deeply meaningful for them. Self-identified queer and transgendered women en gage with digital technologies in order to transform their bodies, not to play at switching gender identities online.

Scholar-activists who wish to challenge the status quo of racial and gender domination have also been slow to seize the opportunity of engaged public discourse offered by the Internet. Risman (2004) urges feminist sociologists to find means to transform as well as inform society, and the Internet offers such an opportunity. Yet, curiously, most academic sociologists do not have an Internet presence beyond their college or university-sponsored faculty webpage, they do not create content for the Internet, and they do not participate in online communities or social networks. I echo Michelle Wright's call for scholar-activists to engage with the Internet "beyond email" (Wright 2005, 57). It is critically important for those of us who hope that our work can and should speak to audiences beyond the academy to follow the lead of critical cyberfeminists and "hollaback" by engaging the Internet as a discursive space and a site of political struggle.

NOTES

1. Throughout this essay I use the term "self-identified woman" and its plural to both recognize the problematic universalizing of difference in the terms "woman" and "women" and to signal the inclusion of queer and transgendered women who may or may not have biologically female anatomy.
2. For example, U.S.-based GenX blogger Kristie Helms writes: "I've been posting journal-type entries online in some form or another since 1996 when I was. Oh. 25. Various places. . . . Through all of that, I've gotten divorced, gotten annulled, changed/ discovered sexual orientation, . . . moved from Manhattan to Brooklyn to Boston, met three life-long best friends over the Internet, . . . bought a house and had . . . urn . . . six jobs, . . . gotten a book published, one essay published, one piece of erotica published (twice), bought three cars, sold two of them, stopped talking to my mother, started talking to my mother, had my father tell me I'm going to hell and just generally keep finding myself periodically" (personal communication, June 2007). While Gill may regard these elements as "depressingly familiar," I think that

such an assessment, like history that is only concerned with the events of powerful political leaders, invalidates the substance of what constitutes women's lives.

3. Rosser reviews women's participation in the information technology workforce along with "design" and "use" of technology through the lenses of liberal feminism, radical feminism, "African American and Racial/Ethnic" feminism, and postcolonial feminism. Offering a review that speaks to all the nuances in this literature is well beyond the scope of my project here.
4. O'Brien does not explicitly address switching of racial identities, but in Kali Tal's (2001) review of Nakamura, Tal likens this phenomenon to "racial passing," about which African American scholars have written extensively.

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CHAPTER 22

Gender and Technology

Francesca Bray

INTRODUCTION

One fundamental way in which gender is expressed in any society is through technology. Technical skills and domains of expertise are divided between and within the sexes, shaping masculinities and femininities: Maybe the iconic womanly skill is basketmaking, whereas men should excel at hunting (MacKenzie 1991); or boys must learn to clean their fathers' tools to get a feel for grease before they are taught to use them (Mellström 2004); or poor women raise silkworms and sell the cocoons to rich households where the mistress organizes the tasks of reeling, spinning, and weaving among her servants (Bray 1997); or boys huddle around the computer screen practicing hacking skills, while girls develop new communication codes using emoticons (Lægran 2003b, Miller 2004). In the contemporary world, or at any rate in the Western nations which pioneered industrialization and have thus been able for so long to dominate worldwide production of material and intellectual goods, services, and desires, technology is firmly coded male. Men are viewed as having a natural affinity with technology, whereas women supposedly fear or dislike it. Men actively engage with machines, making, using, tinkering with, and loving them. Women may have to use machines, in the workplace or in the home, but they neither love nor seek to understand them: They are considered passive beneficiaries of the inventive flame. The modernist association of technology with masculinity translates into everyday experiences of gender, historical narratives, employment practices, education, the design of new technologies, and the distribution of power across a global society in which technology is seen as the driving force of progress.

"Since technology and gender are both socially constructed and socially pervasive, we can never fully understand one without also understanding the other" (Lohan & Faulkner 2004, p. 319). A dense web of debate within the field of gender and technology studies, or feminist technology studies (FTS), catalyzes continual advances in studying what FTS terms the coproduction of gender and technology. Explorations of "constructive" tensions in FTS (Lohan 2000) aim to develop innovative analyses of the material worlds we are creating through technology, and of technology's role in shaping local and global configurations of power, forms of identity, and ways of living. Although expressed in different terms, this debate shadows current anthropological concerns with the transformative role and destabilizing potential of technology in emergent configurations of *oikos* (what are the forms of human community?) and *anthropos* (what is a human being?) (Collier & Ong 2005). Yet curiously the two debates are not in dialogue but remain largely unconnected.

Theoretical debates around the gender-and-technology pair principally engage feminist sociologists and historians working in critical technology studies. Nordic social anthropologists and one or two representatives of the Anglophone and French school of the anthropology of technology also contribute to the debates. These scholars argue with each other, collaborate, and contribute to the same collections. FTS scholars draw on feminist philosophers of science and technology such as Harding (1986) and Haraway (1991), and gender theorists such as Butler (1993), who are also regular sources of theoretical inspiration to anthropologists. Yet the absence of overlap between FTS and cultural anthropology is striking. The latter is conspicuous by its absence from FTS state-of-the-field essays (Lerman et al. 1997, Wajcman 2002, Lohan & Faulkner 2004) and important FTS anthologies (MacKenzie & Wajcman 1999, Lerman et al. 2003). Conversely, most cultural anthropologists grappling with flows and subjectivities in the contemporary world, even when they put "technology" at the heart of their research, ignore FTS scholarship and define, delineate, and articulate their key questions and objects of inquiry in subtly different terms.

This essay begins by looking at FTS, its origins and goals, and the concepts and methods it has developed for relating gender and technology. I then turn to the anthropology of technology, which does not highlight gender to the same degree but nevertheless offers useful conceptual frameworks and methods for exploring gender regimes. Gender-technology relations also feature in the anthropology of work, labor, and development, but unfortunately space precludes discussing them here (see Freeman 2001, Ortiz 2002, Mills 2003). Rather, to highlight the ideological and methodological contrasts between social and cultural analyses of technology and the implications for gender analysis, I discuss the treatment of technology in two leading theoretical fields in the cultural anthropology of modernity and globalization: the anthropology of technoscience, and material culture studies. I conclude by asking what forms of engagement might be envisaged between the fields.

FEMINIST TECHNOLOGY STUDIES: THE COPRODUCTION OF TECHNOLOGY AND GENDER

Feminist technology studies has developed in dialogue with the history and sociology of technology, disciplines in which feminist critiques have played a central part in overturning grand narratives and developing new analytical models (Lerman et al. 1997, Faulkner 2001, Wajcman 2004). Feminist sociologists and historians based in the Netherlands, the United Kingdom, and Australia, and a network of Norwegian scholars that includes social anthropologists, have played a prominent role in developing the field.

Arguing that in the modern world an effective engagement with technology is essential to feminist praxis, FTS strives to develop the theoretical and methodological tools to analyze technology and gender simultaneously in equal depth (Lohan 2000, Faulkner 2001). Unlike much other feminist research on technology, which tends to treat technological artifacts as ready-mades, FTS looks to the production of technology as a point of political leverage.

One influential narrative of modernity, a "standard view" (Pfaffenberger 1992) still in common currency today, designates science as the purest and most powerful form of knowledge, the driving force of modernity; technology is essentially the application of science to practical problems. Technology studies long ago rejected this model, insisting that technology must be studied in its own right as a distinctive practice; in the 1980s science studies also came to acknowledge the critical role of technology and its epistemologies in shaping the production of scientific knowledge. Despite exploring the political, cultural, and even cosmological dimensions of technical projects, technology studies long remained gender-blind, focusing on modern industrial and military technologies and reflecting the social realities of the engineering and business worlds in foregrounding Man the Machine-Maker (Staudenmaier 1985).

In the 1970s radical feminists and ecofeminists initiated a critique of the inherently patriarchal nature of technology, and of technoscience more generally. Here the perils of essentialization surfaced: Some feminists condemned all technology as intrinsically oppressive of women; others perpetuated stereotypes of women as inherently nurturing. Socialist feminists generally tried to be more contextual in their work, pushing Marxist analysis beyond class to ask why and how modern Western technology had become a male domain; to address the gendering impact of modern divisions of labor and of the assignation of women to the domestic sphere; to expand the spectrum of significant technologies to include refrigerators as well as space probes and suspension bridges; and to explore the reproductive and ethical as well as the productive effects of labor organization or of technological design (Oakley 1974, Cockburn 1983, Corea et al. 1985, Kramarae et al. 1988, Wajcman 1991). Cowan's landmark study of household technologies (1983) undermined the common belief that technology makes our lives easier, showing how mechanization served to raise cultural standards of cleanliness rather than freeing women from domestic drudgery. Through interrogating concepts such as technological efficiency and significance (Stanley 1993), FTS has broadened the scope of technology studies to include such assemblages as the brassiere, the closet, and the white collar (McGaw 1996). Feminist studies of the engineering profession charted the institutional, social, and cultural barriers against women (Arnold & Faulkner 1985, Cockburn 1985, Bucciarelli 1994). The FTS agenda was both intellectual and political: While undermining gender stereotypes and masculinist accounts of modernity, the ultimate goal of feminist technology studies was, and remains, the translation of scholarship into feminist praxis (Faulkner 2001, Wajcman 2004). FTS follows the technology studies agenda in studying technology as a distinctive domain, but like feminist science studies (Harding 1986) it interrogates its gendering at every level (Cockburn & Ormrod 1993).

In the late 1980s constructivist approaches emerged in technology studies that shifted theoretical and empirical attention from engineers' decisions to the complex social negotiations and contestations, the heterogeneity of expertise, of interest groups, and of material or institutional networks involved in technological innovation and in the stabilization or redesigning of artifacts (Bijker et al. 1987). The concept of "sociotechnical systems" reflected the principle that the social and the technological are inseparable, a "seamless web" (Hughes 1986). Marxist scholars unmasked the politics embodied or encoded in the design of technological artifacts (Winner 1986, Feenberg 1999). Actor network theorists proposed treating artifacts as having agency: These nonhuman actors may resist enrollment into our technological projects; furthermore we may delegate to nonhuman actors moral as well as material roles, inscripted into their design (Akrich 1992, Latour 1992).

A core interest of constructivist studies of technology is how artifacts (mass-produced bicycles, electrical supply systems) come to be as they are (Hughes 1983, Pinch & Bijker 1987). This approach initially tended to keep the focus of analysis upstream, looking at the processes of conceptualization and the marshalling of resources that go into design, production, and marketing. As feminist critics noted, in modern industrial societies an upstream focus may exclude women. However, the artifact itself, or its representation through instruction manuals, advertisements, marketing, or the media, can often be shown to incorporate "configurations of the user," including "gender scripts," for instance, shaver models that inscript male desires to tinker versus female preferences for simplicity (van Oost 2003) or cars marketed to men as powerful, to women as reliable (Hubak 1996).

FTS scholar Cowan first brought attention to the importance of the consumer in determining the success or failure of technologies. She defined the "consumption junction" as "the place and time at which the consumer makes choices between competing technologies" (1987, p. 263). Once consumers (or rather users), like producers, were treated as rational actors embedded in complex sociotechnical and cultural systems, it became easier to explain their decisions to adopt or to refuse a technology, as well as the degrees of "interpretive flexibility" to which they might subject it (Parr 1999, Lægran 2003a).

This shift of attention downstream, to consumers, mirrored a broader trend in social and cultural analysis toward studying consumption as the principle site for the production of meaning and the reproduction of power relations in modern societies. In technology studies, however, the role of consumer is more complex, interesting, and powerful than is usually the case in cultural studies. In technology studies consumers are users (or refusers), engaging actively—sometimes positively, sometimes negatively—with the physical as well as the symbolic dimensions of the artifact (Oudshoorn & Pinch 2003). New technologies are often threatening and unfamiliar. To be incorporated into our lives they must be successfully "domesticated" (Sørensen & Berg 1991, Silverstone & Hirsch 1992, Lie & Sørensen 1996). At one level we learn to adapt to the technologies, acquiring and communicating technical skills and developing uses and meanings—including gendered subjectivities—within "communities of consumer organizations in the postwar incorporation of American-style kitchens into European homes, consumption styles, and social values—and also into safety regulations, systems of energy supply, and brand rankings. Other studies compare patient activism around cancer testing in the United States and the United Kingdom (Parthasarathy 2003) or the impact on regulatory policy of global practice" (Wenger 1998, Mellström 2004, Paechter 2006). Equally important is the feedback upstream of intended and unintended uses. So-called "user-centered design" is now routine in many industries (Oudshoorn et al. 2004), and the choices and subjectivities of nonusers are becoming just as important to industry (and to social scientists) as those of users (Kline 2003, Wyatt 2003).

In the introduction to the second edition of their influential collection on the social shaping of technology, Mackenzie & Wajcman urge researchers to continue to examine "the specific ways in which this shaping takes place . . . [for] if the idea of the social shaping of technology has intellectual or political merit, this lies in the details" (1999, p. xvi). But how might case studies best be connected to cast light on broader political configurations? FTS does not share the current obsession of anglophone anthropology with theorizing globalization. Rather, it proposes the concept of integration as an approach to processes of interpenetration and patterns of homogenization or heterogeneity within a community, nation, region, or global network. On one level, technological integration hinges on the effective interconnection of technical hardware and expertise; on another level, it is a political, social, and cultural process (Arnold 2005, Misa & Schot 2005). Although "users" remain a key focus in FTS, one recent integrative approach, the "mediation junction" (Oldenziel et al. 2005), locates stakeholder interactions, coalitions, and contestations within overarching contexts of regulation or policy, and of state, market, and civil society (see also Oudshoorn & Pinch 2003, pp. 101–90). Oldenziel et al. highlight the importance coalitions supporting or contesting genetically modified crops (Bray 2003).

Another prominent concern in current FTS is the exploration of femininities and masculinities, their performance through technology, and issues of practice, skill, and embodiment, including emotions, pleasure, sexuality, and eroticism (Law 1998, Law & Singleton 2000). Together with Butler's analysis of gender as performance, Connell's (1995) concept of "hegemonic masculinity," "the configuration of gender practice which embodies the currently accepted answer to the problem of the legitimacy of patriarchy" (p. 77), serves FTS scholars as a tool to explore how particular gendered identities are attributed, achieved, and performed and their place within broader configurations of power.

Wajcman has noted a distinction between two expressive and constitutive forms of masculinity, both connected to the mastery of technology. One is based on toughness and practical skills (e.g., the mechanic), the other on intellectual acuity (e.g., the software designer) (Wajcman 1991). Horowitz's collection *Boys and their Toys?* (2001) examines "manhood in the workplace," "learning to be men" and "manhood at play." Faulkner and her colleagues explore different ways in which men and women talk about their technical aptitude, setting these self-representations against actual practice (Faulkner 2000, Kleif & Faulkner 2003). Mellström (2003) has studied the relation between technologically configured masculinities and state ideologies of modernity in Malaysia; how the embodied "learned dispositions" of mechanics are fostered and transmuted from father to son (2002); and the uses of leisure artifacts such as motor-bikes in male bonding in Sweden and Malaysia (2004). Although the equation between masculinity and technology in Western societies is durable, there are often huge mismatches between image and practice so that fractured and contradictory constructions of masculinity often coexist (Faulkner 2000). Meanwhile research on non-Western societies challenges these associations. Lagesen's research in Malaysia, for example, shows that young women enter the profession of software engineering in roughly equal numbers to men and believe that their different practices of problem-solving are equally conducive to excellence (Lagesen 2005).

FTS scholars use the term coproduction to designate the dialectical shaping of gender and technology. The concept is intended to highlight the performative, processual character of both gender and technology and to avoid the analytical and political pitfalls of essentializing either (Grint & Gill 1995, Berg 1997, Faulkner 2001). In modern societies gender is constitutive of what is recognized as technology, determining whether skills are categorized as important or trivial (Bowker & Star 1999). An electric iron is not technology when a woman is pressing clothes, but it becomes technology when her husband mends it. A woman engineer who tests microwave ovens is told by her male colleagues that her job is really just cooking (Cockburn & Ormrod 1993). In the 1970s computers were thought of as "information technologies" and coded male; it was widely assumed that women would have problems with them. By the 1990s computers had also become "communication technologies"; now it was presumed that women would engage with them enthusiastically. "New technologies spur processes of boundary work and renegotiations of what is to be considered masculine and feminine" (Lie 2003a, p. 21; Lohan 2001).

In terms of praxis, the overarching goal of FTS is to analyze how technology is implicated in gender inequalities to work toward more democratic forms of technology. Noting the relatively limited potential of consumer intervention for democratizing technologies from the outside in, some FTS scholars suggest that rather than continuing to focus predominantly on consumption, identity, and representation, FTS should return to production and work, or to the gendering of design processes and the gender subjectivities of designers, as research sites (Oudshoorn et al. 2004, Wajcman 2004). An important paper by Suchman (1999), based on an anthropological consultancy for technology design in a large industrial enterprise, draws on Haraway and on labor theory to propose new modes of feminist objectivity, rooted in densely structured and dynamic landscapes of working relations that destabilize the boundaries between producer and user. Documenting the masculinist ideologies of the engineering world and exposing prevalent stereotypes about women and technology may both contribute to democratizing technology from the inside out. Eventually they might inflect prevailing ideologies of technology. More modestly, given that gender systems are more difficult to change than are material technologies, they suggest ways to encourage more women to become engineers or to reshape state or industry policies of training and employment (Kvande 1999, Gansmo 2003).

ANTHROPOLOGY OF TECHNOLOGY, ANTHROPOLOGY OF TECHNIQUES

Within the American tradition of cultural anthropology, technology has generally been viewed "as a context for, rather than a central part of, culture" (Wilson & Peterson 2002, p. 450). Pfaffenberger (1992) lays out a melancholy history of neglect, dating back to Malinowski's declaration that the study of technology alone was scientifically sterile (1935, p. 460) and to Kroeber & Kluckhorn (1952, p. 65), who rejected the term material culture on the grounds that the culture was the idea behind the artifact. Technology continued to be studied by archaeologists, cultural ecologists [including Geertz at an early point of his career (1963)], and development anthropologists; feminist archaeologists have been particularly productive in rethinking gender-technology relations (Gero & Conkey 1991, Wright 1996). Yet within mainstream cultural anthropology in the United States, technology was not an object of analysis in its own right, and no recognized field of anthropology of technology emerged (Pfaffenberger 1992, Suchman 2001). This antimaterialist aversion was less marked in British social anthropology, but despite some distinguished studies and original theoretical claims (Goody 1971, 1986; Sillitoe 1988; Gell 1992; Ingold 2000), there too anthropological interest in technology as a theorizable category has remained muted.

In 1992 Pfaffenberger published an impassioned call to anthropologists to take technology seriously. Anthropology was uniquely qualified, he argued, to answer important questions about technology as a universal human activity. He proposed translating the concept of "sociotechnical systems," borrowed from technology studies, into a template for anthropological study, laying a basis for comparative analysis of the place of technologies in the generation of meaning, in precapitalist as well as capitalist societies. In 2001 Pfaffenberger once again lamented "the enormous cost of Anglo-American anthropologists' penchant to ignore technological activities" (p. 84). His paper appears in a wideranging collection of perceptive and original essays on technology by archaeologists and anthropologists. But theoretically and methodologically they sprawl: a noble attempt by the editor to extract a coherent agenda for an anthropology of technology reads like a list, not a program, and gender is not mentioned (Schiffer 2001b).

Among the few American anthropologists to take technology seriously as technology are Suchman and Downey. Both work among engineers, focusing on the design and production of technologies, the business contexts in which they are developed, and the material incorporation of values and worldviews into artifacts such as bridges or CAD/CAM technology (Downey 1992, 1998; Suchman 2001). In an essay advocating "cyborg anthropology," Downey et al. (1995) propose close anthropological attention not only to representations or consumption of technology, but to the cultures of the technical communities that produce technologies and to the specific material effects of technology on perception, communication, and identity. The authors propose cyborg anthropology as an action-oriented agenda, aligned with FTS, that would engage the general public and unmask the material as well as cultural dimensions of domination by race, class, and gender.

From her uncharacteristic perspective as an anthropologist working with industry, Suchman (2001) distinguishes three aspects of research on contemporary technology: (*a*) ethnographic studies of sites of technology production; (*b*) studies of technologies-in-use; and (*c*) ethnographically based design interventions. Although aspect (*c*), rooted firmly in aspects (*a*) and (*b*), would be the goal of feminist technology studies, anthropological studies of technologies are usually limited to aspect (*b*). In the absence of sustained debate around technology as a distinctive category of material activity, rather than just another source of metaphors, it is not surprising that most anthropologists prefer just to look at the dimensions that are most obviously cultural productions. As Axel (2006) notes, anthropologists writing on emergent technologies, for example, information and communication technologies (Hakken 1993, Escobar 1994, Wilson & Peterson 2002), invariably claim that anthropology as a discipline is particularly well suited to charting their emergence. Yet these are accounts not of technology per se but of specific technologies, and it is not clear that they offer anything distinctive from analyses produced in other branches of cultural studies.

Over decades of intensive debates in the pages of *Techniques et culture* and other francophone journals, the French school of anthropology of techniques, which also includes archaeologists, economists, engineers, historians, and sociologists, has developed specific theoretical and methodological repertories for the comparative study of technologies. The convention of defining technique to include bodily practices (*techniques du corps*) as well as the use of tools dates back to Mauss, who saw *techniques du corps* as distinctive cultural practices, and to Leroi-Gourhan, who treated tool and anatomy as inseparable in his analysis of the logic of technical action. The French approach begins with detailed attention to "operational sequences" or *chaînes opératoires,* "the series of operations involved in any transformation of matter (including our own body) by human beings" (Lemonnier 1992, p. 25). From systematic observation of the operational sequences of production or use, analysis proceeds to what Lemonnier calls the "social representation of technologies": This denotes not only the kinds of meaning that usually attract the attention of cultural anthropologists, but also the ideas governing the construction and use of tools and artifacts, an ethnoscience of material nature and action.

Skills (*savoir-faire*), documented through operational sequences, are a key focus in which material, mental, social, and cultural resources converge (d'Onofrio & Joulian 2006). The analysis of technological choices or styles goes beyond, but must account for, the relevant material affordances or constraints and systems of technical skill and understanding (Lemonnier 1993). The core observational and analytical methods may be deployed within a variety of overarching frameworks, including actor network theory (Latour 1993), modes of production (Guille-Escuret 2003), or anthropology of ritual (Lemonnier 2004). The approach spans high tech, low tech, and no tech, from the design of high-speed urban transportation systems (Latour 1996), through the rocky negotiations of technology transfer (Akrich 1993), to gender differences in Indian pottery making (Mahias 1993) or the place of posture in Chinese femininities (Flitsch 2004).

Similar to the American anthropologists of technology, the French school views technology as a universal human activity and emphasizes the need to build strong analytical and empirical bridges between upstream and downstream, artifact production and use. Its conceptual frameworks and methods are designed to apply equally to old or new technologies. Scholars such as Mahias (2002) have deployed them brilliantly to illuminate the interpenetration of "traditional" and industrial, local and "global" technologies and technological cultures. Although gender-technology relations are not as prominent or sustained a theme as in FTS, the methods lend themselves to finely textured studies of gendered identity, some focused on individual technologies or bodily practices (Desrosiers 1997, Darbon et al. 2002, Pardo 2004), others on gendered repertories of technical skills (Mahias 2002). Although Latour's study of Aramis (1996) has been criticized for gender blindness (Wajcman 2004), it offers rich materials for the study of masculinities. In a study of imperial China, Bray (1997) documents the historical dynamics of a "gynotechnics," mutually shaping technologies of dwelling, production, and reproduction central to hegemonic and pragmatic gender identities. Refining the concept of *techniques du corps,* Ingold (2000) proposes treating the skills of craft and of art under the same heading and highlights their ontogenetic nature. Far from being added onto a preformed body, skills grow with the body: "[T]hey are fully part and parcel of the human organism, of its neurology, musculature, even anatomy, and so are as much biological as cultural" (p. 360). This approach suggests bridges to recent FTS researches, inspired by Butler (1993), on the "achievement" of gender (Lie 2003a).

ANTHROPOLOGY AND TECHNOLOGY

Classic anthropological monographs, including Malinowski's, are rich in materials on technical activities and their meanings (Malinowski 1935, Pfaffenberger 2001). Examining the articulations of work, production, and skills with exchange, ritual, kinship dynamics, and social differentiation, they address, as does FTS but implicitly, sociotechnical systems, "seamless webs" of material, social, and symbolic practices and relations. Although not expressed in these terms, classic anthropology contributed some fine precursors to the study of technology and gender, for instance in studies of sexual divisions of labor (e.g., Richards 1939, Hugh-Jones 1979).

Once the concept of gender became a specific analytical focus, feminist scholars focused on technical practices, old and new, to retheorize core anthropological concepts radically, including kinship (Strathern 1992), exchange (Weiner 1992), or space (Moore 1986). As the anthropology of gender fused with the anthropology of modernity and of globalization, attention turned to the role of technoscience in reshaping gender regimes. And with the broader cultural turn emphasizing the importance of consumption as the constitutive site of subjectivities and power, the new field of material culture studies contrived a radical new antiessentialist perspective on technologies.

Anthropology of Technoscience

Technology and such derived concepts as "technoscapes" or "techno-nature" figure prominently in recent anthropological theories of the place of technoscience in modernity and/or globalization. Key concerns of anthropological studies of technoscience, as of FTS, are the formation of the modern subject and the distribution of power through emerging global networks. However, Escobar (1994) explicitly distinguishes the agenda of the anthropology of technoscience from that of the sociology of technology: "For anthropologists, inquiry into the nature of modernity as the background for current understanding and practice of technology is of paramount importance. In this anthropology is closer to the philosophy than to the new sociology of technology" (p. 213). The culturalist approach to technoscience, like the "standard view," is interested first and foremost in science, powerful knowledge instrumentalized through technology. Technologies are of anthropological interest as phenomena emerging from particular cultural contexts, contributing to new cultural worlds such as "cyberculture" or "techno-nature" (Escobar 1994, 1999).

In destabilizing boundaries between the human and the natural or between human and machine, promoting new, troubling relations of intimacy, or facilitating new forms of governmentality, emergent technologies such as in-vitro fertilization, transnational organ transplants, stem-cell research, or data-banks raise new questions of "how to live" (Collier & Lakoff 2005). New technologies may be conceptualized as prostheses, elements of cyborg fusions between human and machine that extend our capacities and permit enhanced modes of being and relating; new forms of interpenetration of zones of space and time; and new possibilities for action at a distance, for connection, coalition, or control (Axel 2006, Rafael 2003, Wright 2001). They may figure as tools for both research and accumulation, concentrating capital or biocapital in certain sites while providing the material procedures and equipment for the domestication of new life forms such as stem cells (Franklin 2005). The term global assemblages has been proposed to address the spatial and political dynamics of these restless flows and concentrations of material and symbolic resources (Ong & Collier 2005).

Most work within the anthropology of technoscience that explicitly attends to gender-technology relations addresses biopower and its new subjects: the new masculinities or femininities achieved through remakings and resexings of the body; or through cross-class, transnational, or interethnic reconfigurations of kinship and reproduction (Kaufman & Morgan 2005). Analysis focuses on the potentialities and interpellations inherent in the new science and its representations; on users as "ethical pioneers"; on interactions between experts and technicians and the "lay" users (or refusers) of biomedical services; and on "lay" appropriations or contestations of new disciplinary regimes (Rapp 1998, Greenhalgh 2005). However the technological apparatus itself is usually left as a black box. Despite Downey's cyborg manifesto, there are few anthropological studies of the material production or design of the technologies of biopower, cybercultures, or techno-natures. Rabinow's illuminating biographies of technology, studying the coproduction of technological apparatus, technocracy, research agendas, and scientific imaginaries, are rare anthropological analyses of the power inherent in the nuts and bolts of technology (Rabinow 1996, Rabinow & Dan-Cohen 2005). Traweek's classic upstream study of the mechanical foundations of high-energy physics (1988), which explicitly explores the gendering of technocratic production and practice, is another exemplary rarity.

Material Culture Studies

The anthropology of technoscience engages with heroic technologies, such as DNA sequencing or organ transplantation, that promise to transform what it means to be human. Material culture studies (MCS) currently takes up the challenge of decoding the mundane technologies of everyday life such as kitchen equipment or cars, analyzing the role of material artifacts in producing subjectivities and social relations. As a counterbalance to classical Marxist analyses that treated work and production as the loci where identity and meaning were produced, the cultural Marxism of MSC prioritizes meaning and identity production through the social processes of consumption (Miller 1995). One theoretical concern of MCS is to critique the reification of globalization by demonstrating that the "global" is always manifested and experienced as a "local" phenomenon. Widely viewed as global in nature, yet intrinsically cultural in their use, the new communications technologies offer irresistible test cases.

MSC studies of the Internet in Trinidad (Miller & Slater 2000) or of cell-phones in Jamaica (Horst & Miller 2005) generate richly textured analyses of how technology use intertwines with sociality, including the expression and affirmation of gendered identities and forms of intimacy and relatedness. They also document the gratifying extension of Jamaican or Trinnie styles of communication across transnational spaces, transforming the experiences of migration or diaspora. The point is convincingly made that Caribbean Internet users are not reacting to globalization but creating it. By insisting that the new technologies facilitate but do not determine these cultural extensions, these studies reflect the MCS position on "materiality."

MCS proposes the concept of materiality to transcend the object-subject divide, viewed as an enduring weakness of Western thought. One might have thought this would open up very interesting possibilities for theorizing technology, skills, and subjectivity. However, in repudiating reification of the object, MCS specifically dismisses technology as an analytical category. Although Miller develops methods for charting the extension of technology use that correspond to the specific ways in which the Internet or cell-phones work, he insists that the primary interest is how they are brought into being as cultural artifacts. It is correct, as Miller asserts, that the Internet is in constant flux, its features continually reworked by its users. Yet even the Internet involves a framework of technical design, costing, and regulation (local or transnational) that channels and constrains the forms of communication and sociality it allows (Wilson & Peterson 2002, Wilk 2005). Miller's studies of communications technologies are actually rich in detail on the political-economic context within which they were launched and adopted, and on user skills, technical as well as social. Generally speaking, however, MCS is open to criticism for excessive culturalism: "while the demolition of the essentialized object was an urgent necessity, the declaration of objects' and images' emptiness has become a proof for an anthropology committed to the victory of the cultural over the material, and of the discursive over the figural" (Pinney 2002, p. 259).

FRUITFUL EXCHANGES?

The interdisciplinary field of feminist studies of technology has done more than any other social science to build a vibrant and coherent school of gender and technology studies. FTS has drawn heavily on ideas and methods developed within anthropology: the integrity of social action and culture; the "micro-macro" linkage of everyday skills and techniques and political-economic activities; and detailed empirical observation and broad-ranging comparative analysis. Could we now envisage more explicit and sustained forms of engagement among different branches of anthropology and FTS, to strengthen our understanding of gender-technology relations in a rapidly changing world?

Philosophically, FTS and the anthropology of technology share a strong materialism in their approach to culture-technology dialectics. Exchange between the fields therefore presents few epistemological problems. FTS lacks research on gendered dimensions of technical skills (Faulkner 2001), and here methods developed by the French school for documenting operating sequences and *savoir-faire* might prove helpful. In considering the full spectrum of gender subjectivities achieved or imposed through technology in different contexts, another obvious lack in FTS at present is studies of non-Western societies, past as well as present. The anthropology of technology, by theorizing technology as a universal human activity, offers not only a rich spectrum of non-Western and premodern case studies, but also analytical frameworks for reintepreting historical and ethnographic documents from FTS perspectives.

In its attention to the materialities of everyday life, the French school of anthropology of technology shares common ground with MCS, but fundamental disagreement about whether technology constitutes an analytical category is a serious barrier to dialogue. It is not totally insurmountable, however. Dant (2005) argues for the value of incorporating more attention to technical skills and practices into MCS analysis; some contributors to *Material Culture Studies* focus on technological goods as technologies (Shove & Southerton 2000); and French practitioners of MCS have successfully borrowed from the anthropology of techniques, integrating analysis of production and skills into their studies of consumer culture (Warnier 1999, Faure-Rouesnel 2001). Were anglophone MCS to tread a similar path it might have to abandon some ambitious idealist claims about materiality. Yet valuable new insights into the coproduction of technology and gender might result if the strengths of MCS in charting the coproduction of global and local culture were extended to acknowledge technology. This would also provide a neat way for MCS to incorporate global flows of financial, corporate, and regulatory power more fully into their analyses.

The anthropology of technoscience attends closely to these global flows of power, and despite significant philosophical differences with FTS, there is a strong case to be made for closer dialogue between the fields. Concepts such as sociotechnical systems, stabilization, and integration allow FTS to explore how technologies and the associated politics of gender travel across space and time and how they consolidate into systems that resist change.

These approaches, along with FTS methods for studying the design and production of technologies, could enhance technoscience studies of biopower and of global assemblages. Attention to the gendering of technical design would be particularly valuable in advancing understanding of biopower. Conversely, in focusing so closely on the gender-technology nexus itself FTS sometimes neglects deeper-lying ideogical dimensions within which any regime of truth concerning gender and technology must ultimately be understood, and which the anthropology of technoscience takes as its object, namely emergent configurations of *oikos* and *anthropos.*

DISCLOSURE STATEMENT

The author is not aware of any biases that might be perceived as affecting the objectivity of this review.

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CHAPTER 23

Queering Feminist Technology Studies

Catharina Landström

This paper examines the ways in which heteronormativity influences feminist research on gender and technology. It draws attention to the ways in which heteronormativity shapes analyses and concepts in empirical investigations, which is an issue in need of more critical debate (cf. Susan Driver (2005) and Victoria Hesford (2005)). The discussion also addresses the divide between a theoretical discourse that fully accepts 'the end of the binary of femininity and masculinity', and empirical research that 'relapse[s] into the old pattern' (Van Lenning, 2004: 26) within feminist technology studies.

The analysis focuses a particular research trajectory that will be called 'feminist constructivist technology studies', which is committed to investigating the 'coproduction' of gender and technology (Faulkner, 2001). This sub-field within the wider area of feminist technology studies relies on ethnographic methods to analyse gender in relation to the construction and use of technology. This sub-field resists technological determinism but tends to 'black-box' gender identity as the major cause in the gendering of technology, which leads to analyses representing gender as stable and technology as malleable. This can be understood as a result of a failure to adopt new ways of theorizing gender. One reason for this shortcoming is the habitual reproduction of heteronormativity, which prevents a constructivist approach to gendered subjectivity. Instead the gendered subject functions as the determining factor in the gender/technology relationship, which counteracts the explicit objective of understanding coproduction.

The following discussion criticizes the ways in which heteronormativity is reproduced in ethnographic case studies and points to alternative feminist conceptualizations of the gendered subject. It is suggested that perspectives drawing on queer theory can contribute to a rethinking of gender in this strain of feminist technology studies. The examination begins with a presentation of feminist constructivist technology studies, illustrated with examples of how heteronormativity shapes the representations of women, men and technology. This is followed by a discussion of other, more open-ended feminist approaches to gendered subjectivity in relationships with technology. Finally, the paper turns to feminist elaborations of queer theory, in an argument for the benefits of shifting the theoretical framework, in order to facilitate the objective of analysing the coproduction of gender and technology.

FEMINIST CONSTRUCTIVIST TECHNOLOGY STUDIES

Feminists have interrogated the relationship between gender and technology for at least three decades.[1] The works subsumed under the label 'feminist constructivist technology studies' in the present article comprise a sub-field within the area.[2] They investigate the construction of technology and its users in empirical case studies often by way of ethnographic research among engineers, designers and users of technology. This empirical research is conceptually interesting because it attempts to formulate constructivist perspectives toward both technology and gender. The analyses aim to critically capture the ways in which technology is shaped by gender and gender is shaped by technology.

Wendy Faulkner (2001) outlines the agenda of this research to a wider feminist audience in a way relevant to the present article. She understands its propelling force to be the question of how technology is gendered, a question that becomes possible by adopting a social constructivist perspective on technology.

Constructivist approaches to technology emerged in the field of social studies of technology as an explicit rejection of the technological determinism dominating previous social, historical and philosophical analyses.[3]

They argue that technology is always shaped in complex processes that involve social and cultural factors, as well as material and technical elements. Today constructivist perspectives range from applications of social theory, to radical re-conceptualizations of subjectivity and causation.[4] Feminists take social constructivism as one point of departure, assuming that technology is not socially neutral, but that it embodies social relationships, including gender, which order the contexts of creation and use. Faulkner argues that this perspective 'obliges us to view gender *as an integral part* of the social shaping of technology' (2001: 90, emphasis in original).

Feminist constructivist technology studies combine this perspective on technology with a view of gender as socially and culturally produced. The research is guided by 'the sense that technology and society are mutually constituting—hence, the coproduction of gender and technology' (Faulkner, 2001: 90). Technology is, in this view, created and used in a changing, socio-cultural system, and gender, as a feature of this system, is also shaped by technology. This adoption of a constructivist perspective on technology, fused with an understanding of relationships with technology as impacting on the processes that shape gender, can be considered a 'double constructivism'.[5] To deliver on this promise a symmetry in the treatment of gender and technology, in relation to each other, is called for. So far the bulk of research in the field has focussed on the gendering of technology. Results have confirmed that technology is dominated by men and associated with masculinity, and that it is easier for men to relate positively to technology (Cockburn, 1985; Wajcman, 1991; Rommes, 2002). A recent example is Nelly Oudshoorn, Els Rommes and Marcelle Stienstra's (2004) article about the ways in which software engineering communities construct the user's position. The authors explicitly commit to a constructivist approach; they aim to understand the ways in which engineers' ideas about users inform the design process. Through ethnographic research in two comparable software design projects, both constructing systems intended for public use (DDS and New Topia), they discovered that, despite initial ambitions to produce designs that work for 'everybody', both projects ended up using what they term the 'I-methodology', i.e. designers taking themselves as the model for the user. The user was expected to be intrinsically interested in exploring the way the computer program worked. The researchers conclude that the process generated a user-position that favoured young men with an interest in computers:

> Since the project teams of New Topia and DDS consisted mainly of men, and the few women involved in the design of the DDS largely adopted a masculine design style, the interests and competencies inscribed in the design were predominantly masculine. The fact that DDS and New Topia failed to attract the audience they intended to reach must therefore also be understood in terms of the gender identity of the designers. (Oudshoorn et al., 2004: 53)

The conclusion that the engineers' gender identity produced the effects seems strange when the authors have conceded that women can 'adopt a masculine design style'. Men's gender identity becomes a stable factor, with the force to determine technology design. The women engineers appear not to have gender identities of the same strength, since they can adopt the required masculinity, while the female non-users' position is determined by their gender identity. This statement illustrates an analytical asymmetry, which has haunted feminist constructivist technology studies from the outset.

More than ten years ago Rosalind Gill and Keith Grint (1995) identified several points of contention in the meeting between constructivist perspectives on technology and feminism. One was the risk of 'black-boxing' gender as an analytical tool, which leads to 'an artificial analytic closure' (Gill and Grint, 1995: 20). This appears to be what has happened in the example above and in other studies. Whilst feminist researchers have effectively appropriated and further developed a constructivist approach to technology in the ten years that have passed, their conception of gender seems to have congealed. The gender identities of technology designers and users are treated as stable traits that precede the creation of a malleable technology. This 'black-boxing' of gender undermines the aim to understand the coproduction of gender and technology. If gender is already there, as a fixed element it can only function as a cause in relation to the socially constructed technology. When, as in Oudshoorn, Rommes and Stienstra's article, the gender of the engineers is used to explain the masculinity of the projected and actual users, we end up with a 'selective relativism' in which 'some things are seen as constructed but not others' (Gill and Grint, 1995: 20).

A double constructivist analysis needs to be able to account for the gender of engineers as also being constructed in the process of creating technology and projecting users. This is something that Oudshoorn, Rommes and Stienstra hint at in their observations of female software designers, who do things in the same way as their male colleagues do, but it does not influence their conclusion. To address this they would have to approach gender not as an identity trait that comes from within the individual and determines their relationships with others, but as something emerging in the processes in which people and technology are enmeshed. Feminist theorists have developed a number of ways to think differently about gender, but apparently these have not caught hold in feminist constructivist technology studies. Instead of addressing this head on, as if scholars in this sub-field had no knowledge of these approaches, I want to begin with a critique of heteronormativity, which I believe presents a major obstacle to the adoption of more open notions of gender.

HETERONORMATIVITY IN FEMINIST CONSTRUCTIVIST TECHNOLOGY STUDIES

Heteronormativity, 'as the view that institutionalised heterosexuality constitutes the standard for legitimate and expected social and sexual relations' (Ingraham, 2002: 76), influences the way in which gender is represented and discussed in feminist constructivist technology studies. Texts in this field do not question the definition of gender as a heterosexual coupling of opposites, female and male, masculine and feminine. They represent heterosexuality as the model for all relationships between humans and between humans and technology. The analyses take the local production of feminine women and masculine men, who relate to each other through sexuality, as a factual premise. The absence or disapproval of, for example, masculine women or feminine men, who may (or may not) relate to each other in different ways in the studied communities, is not seen as in need of explanation.

Heteronormativity is not something that feminist constructivist technology studies bring to their subject matter. However, they have, as of yet, not problematized it, neither in the communities they study, nor in their own analyses; this in spite of knowing that it is present in their empirical material and in the wider socio-cultural environment. That heteronormativity influences social relationships, not just intimate personal connections, ought to be a topic for a critical analysis in research that has as its foundation a belief that technology is created in social relationships, carrying social meanings and expressing social norms. Heteronormativity can be expected to operate in, and influence, technological environments. Faulkner is obviously aware of the link between femininity, masculinity and heteronormativity as she speaks of the two genders as 'usually posited ideologically on an attraction of gendered opposites' (2001: 88). She also points to 'heterosexism' as an 'under researched theme in the gendering of technology' (2001: 88) that 'may provide at least a partial answer' (2001: 88).[6] However, this insight does not lead to any discernible changes in her own discussion of women, men and technology, nor does it seem to have any impact on the field, as is demonstrated in an article by Elin Kvande (1999), about the ways in which women graduate engineers in Norway construct femininity.

Kvande recounts the words of one of her interviewees:

> 'A female graduate engineer cannot dress in lace and frills because she won't be taken seriously', says one woman working as a graduate engineer. Many of these women have relatively clear ideas as to how they can express their femininity. We can also interpret this to mean that female graduate engineers have to be 'one of the boys', or 'social men', to be accepted and given career opportunities in organizations. (Kvande, 1999: 305)

Kvande does not discuss the informant's designation of femininity as 'dressing in lace and frills', which I will return to later on. At this point another issue is in focus—that this analysis implies that femininity is something that women have and can choose to express.

The construction of women as possessing femininity, opposed to masculinity that emerges from men, runs through Kvande's analysis. The main part of her text describes four strategies for 'expressing' femininity in male dominated workplaces. Kvande names these 'homeless', 'one of the boys', 'compensators' and 'challengers'. The 'homeless', often new in the workplace, 'adhere to the rules of behaviour' in order to 'fit in as much as possible and be accepted' (1999: 311). The women opting to become 'one of the boys' aim to be ' "like" their male colleagues and to be treated like them' while they distance 'themselves from "the majority" of women' (1999: 311). These two strategies are, according to Kvande, based on an idea of 'sameness' while the remaining two accentuate 'difference'. The 'compensators' actively distance themselves from the culture of the profession and withdraw from it 'in favour of their other tasks, interests and values as mother and family member' (1999: 312). The 'challengers' also reject existing norms in the workplace but take them on, demanding changes that would allow them to achieve their goals of having 'a career as a graduate engineer and . . . a family and children' (1999: 312). These categories are said to be 'ideal types', compiled from interview data, and they reproduce the interviewees' construction of heteronormative gender by assuming that femininity and masculinity are mutually exclusive and emerge from female and male bodies respectively.

In Kvande's analysis there is no possibility for women to express something other than femininity, heteronormatively defined as the opposite of masculinity. The female individuals who adapt to the norms of the workplace and do 'sameness' cannot, in this model, be understood as doing masculinity. This is strange because if the norms of the workplace are understood to define a certain type of masculinity as preferred conduct, the women who try to fit in and live these norms ought to be regarded to be doing masculinity (or at least attempting to).

It is also obvious that Kvande regards the 'sameness' strategies as less sound options, as something forced on to the women but not tenable in a longer perspective because 'having children will shatter the illusion that it is possible to belong to the category "social men" ' (1999: 324). Femininity is thus tied to reproduction. 'Sameness' is also judged to be politically inadequate since it 'prevent[s] the development of solidarity between themselves and other women, and this inhibits a common insight into the conditions women face in society in general' (1999: 323). Hence, women who would fit in with the men at the workplace cannot be true feminists. In the article Kvande merges a claim to apply constructivism with a heteronormative model of sexual difference. In her framework the idea of women doing masculinity is inconceivable, and conduct that could be read in this way is deplored. This echoes a more widespread practice in which 'female masculinity is generally received by hetero- and homo-normative culture as a pathological sign of misidentification and maladjustment' (Halberstam, 1998: 9).[7] Kvande's article reproduces heteronormativity by representing the informants' construction of gender in a way that does not problematize it, but instead establishes and amplifies it as an analytical fact.

Another version of heteronormativity in the field is the assumption that all women relate to technology in a way that reflects heteronormative femininity. An example is Marja Vehviläinen's (2002) article about a Finnish initiative to promote computer literacy among women.

Vehviläinen begins with a discussion of gender and technology and commits to a perspective of 'gender, agency, and technology . . . as social constructions . . . shaped through . . . everyday practices' (Vehviläinen, 2002: 276). She presents ethnographies of two women's groups engaged in teaching computer skills in the late 1990s. The groups were different, with one considerably more successful than the other at bringing skills and confidence to the participants.

Vehviläinen's study is a careful empirical investigation, that most certainly captures the reality of the participants of the two groups, and her critique of 'the liberal view' of technology as neutral and the same for everybody is important. She concludes that '[I]n order to create voices of their own, women need to connect technology to their own experiences, which means struggle and work' (2002: 289). She also argues that diversity among women will only become visible in women's groups that begin from the experience of the participants. In such groups 'there is room for differences between women' (2002: 289). This assumes that differences between women have no relevance for their relationships to technology. In this analysis all women relate to technology in the same way, as outsiders, because technology is gendered masculine. Vehviläinen, thus, represents all women as identifying with a femininity that is the opposite of masculinity, which determines their relationship with technology. This may be true for women who identify with a heteronormative femininity defined in a relationship to masculinity, but not necessarily for those who do not, for example, many lesbians.

Research on lesbians and technology provides reason to believe that the assumption that diversity among women does not pertain to their relationships with technology is mistaken. In relation to computer usage Nina Wakeford's (2002) overview of lesbians online is illustrative. She dates the first online lesbian discussion list to May 1987. She also states that the early lists

> . . . tended to be facilitated by women working in the computer industry who could use the computers at their organisation to run the mailing list distribution software. These women could spend up to four hours per day administering requests for subscription, dealing with messages being returned by nonfunctioning email accounts, or simply moderating the discussion which was happening in the forum. (Wakeford, 2002: 119)

This implies a very different relationship to computers than that which Vehviläinen assigns to 'women'. These lesbians had access to technology and skills that they could use to pursue their own interests.

Other examples of lesbians appropriating computer technology include explorations of hypertext as a medium for writing lesbian poetry (Hawthorne, 1999), a study of how Singaporean lesbians use new media to construct identity and community (Yue, 2003) and an online ethnography in a lesbian chat room (Poster, 2002).[8]

Despite awareness that 'institutionalised heterosexuality' (Faulkner, 2001) plays a role in the coproduction of gender and technology, it appears to be difficult for feminist constructivist technology studies to make analyses accommodate non-heteronormative ways of doing gender in relation to technology. Heterosexual women's relationships with technology are represented as the way all women relate to technology.[9]

Technology is understood as masculine and women's relationships with technology are represented as analogous with heteronormative projections of women's relationships with men. The unquestioned assumption that all relationships between women and men are heterosexually structured, and that this precedes and organizes everybody's relationships with technology, produces an analytical problem. This construction of gender reaffirms the link between masculinity and technology that was conceived as one of the issues that feminist technology studies set out to critique.

Paying attention to lesbians and technology can counteract the overgeneralization of heteronormative femininity to women in general. However, it does not solve the difficulties with the lack of symmetry in a double constructivism, partly because the focus in such studies tends to be on technology use, and partly because they do not question the semiotics of gender associated with heteronormative practices. It is not particularly radical to point out that lesbians are at ease with technology because in heteronormative culture lesbians are often considered to be more masculine than 'women'.

THE SEMIOTICS OF HETERONORMATIVITY

The heteronormative representations of women, men and technology in this feminist field can be examined further with the aid of Judith Butler's (1999) notion of a 'heterosexual matrix'. As a 'grid of cultural intelligibility through which bodies, genders, and desires are naturalized' (Butler, 1999: 194, note 6) the heterosexual matrix defines the logic of heteronormative representation. It is 'a hegemonic discursive/epistemic model of gender intelligibility' (Butler, 1999: 194, note 6) that organizes the way bodies are made comprehensible. It is a logic 'that assumes that for bodies to cohere and make sense there must be a stable sex expressed through a stable gender (masculine expresses male, feminine expresses female)' (Butler, 1999: 194, note 6) in the way that the analyses discussed above do. These stabilized bodies of women and men are, in these studies, also represented as 'oppositionally and hierarchically defined through the compulsory practice of heterosexuality' (Butler, 1999: 194, note 6).

The notion of the heterosexual matrix captures the semiotic order that makes gender heteronormative and the exclusion of lesbians logical in feminist constructivist technology studies.[10] This is no surprise since Butler's concept is, in part, an articulation of critical lesbian feminist thought.[11]

Thought of as a grid with two crossing axes (masculine–feminine and heterosexual–homosexual), the heterosexual matrix allows us to see how the signifier 'women' in feminist constructivist technology studies is positioned in the 'feminine'–'heterosexual' corner. In the same way the signifier 'men' occupies the 'masculine' and 'heterosexual' corner in the grid. To be recognized as a 'woman' it is necessary to remain in the heterosexual–feminine corner.[12] Technology is located on the 'masculine' side of the grid; females with close relations to technology are thus constructed as more masculine. Females doing masculinity and lesbians (who are regarded as expressing a 'masculine' desire for women) are not covered by the signifier of 'women' in this semiotic grid. When 'women' is a heteronormatively constructed category individuals under study can, as in the examples presented above, automatically be positioned in opposition to a masculine technology.

The heteronormative representations of women, men and technology reaffirm the logic of the heterosexual matrix, which reciprocates through naturalizing dichotomous gender as something emerging from the interiors of two different kinds of human beings. This is a material-semiotic process repeated in the everyday of the technological communities studied. However, its habitual reproduction in the representational practices of this field of feminist research has further theoretical consequences, because it also produces gender as interiority. This semiotic order of gender, reproduced in heteronormative practices, is intrinsic to the figure of the modern subject: a notion of the subject which is not conducive to the analysis of 'coproduction', since it stabilizes all that is considered as human in the position of singular, autonomous agent.

The combination of a 'modern' conception of the subject with constructivist notions produces conceptual inconsistencies. This is visible in an article by Tine Kleif and Wendy Faulkner (2003) about men's enjoyment of working with technology. They compared hobby robot builders with software engineers. In the article, which is explicitly committed to the idea of gender as performed, they unpack the content of the pleasure and enjoyment that both groups used to characterize their relations with the respective technology. Kleif and Faulkner analyse, in depth, the links between masculinity and pleasure with technology that were made explicit in both groups. They also note a discrepancy between what the people studied said and what they did, with regard to gender:

> As noted earlier, women's and men's accounts of themselves were more differentiated than their practices seemed to be. Such findings confirm the strength of stereotypes

> around gender and technology as norms; they also confirm that gender is actively performed rather than being laid down in early psychological development. (Kleif and Faulkner, 2003: 315)

With a discrepancy between saying and doing in clear sight and an explicit appreciation of the notion of gender as performed, the suggested conclusion seems a bit odd:

> The authors suggest, tentatively, that technology is a gender-authentic and gender-available avenue for those men who particularly crave certainty because technology appears more certain, easier to understand, and easier to master than other worlds they inhabit. (Kleif and Faulkner, 2003: 296)

'Gender-authentic' is an intriguing phrase in a constructivist analysis. There is no further clarification in the article, only a reference to another publication and a repetition of the same phrase in the abstract. It seems likely that Kleif and Faulkner use the term as a way to account for the way their studied populations perform gender—as if there is something interior to people that is expressed in their relationships with technology. However, this choice of terminology results in a representation of gender as, on the one hand, something that is judged in terms of authenticity and, on the other, performed in ways that oppose speech to conduct. The relationship between the observation of gender differentiation as mainly performed in speech and the conclusion that technology is a 'gender-authentic and gender-available avenue' for 'men who crave a sense of certainty' (Kleif and Faulkner, 2003: 321) seems self-contradicting. The argument appears to draw on two different theories of gender, one focussed on doing and the other on essence. This inconsistency can be understood as resulting from a view of subjects and subjectivity incongruous with a constructivist approach to gender. This is also the point at which the gap between feminist theory and the empirical research on technology becomes visible.

GENDER, TECHNOLOGY AND SUBJECTS

Over the last two decades the wider field of feminist technology studies has conducted an energetic discussion about the constitution of the subject. The constructivist sub-field seems oddly disconnected from this debate. This failure to appropriate new ideas and concepts is a pity, because they open ways of thinking about gender and technology that are conducive to the issue of coproduction. Even paying some serious attention to the well-established notion of the cyborg, that set the discussion off, would help.

As a 'theorized and fabricated' hybrid 'of machine and organism' (Haraway, 1991: 178) the cyborg is a way to understand the ontology of the political feminist subject that takes its constitution in complex relationships into consideration.[13] It is a figure that confuses 'all modes of identity (particularly gender) categorization' (Lloyd, 2005: 16). However, in feminist constructivist technology studies it seems to appear only as a 'buzz word', used without 'effort to think through what it *adds* to call something a cyborg' or 'what *difference* it makes' when we describe the world, to restate a criticism from the mid 1990s (van der Ploeg and Van Wingerden, 1995: 399, emphases in original).[14]

If feminist constructivist technology studies would find Haraway's concept overused or dated, the idea captured in the notion of the cyborg has been further elaborated and reworked in the feminist discussion. The concept has matured enough to make its shortcomings visible.[15] Dianne Currier argued, in this journal, that the cyborg 'ultimately fails to make the break with the logic of identity' (Currier, 2003:

323). She also thinks that there has been a stabilization of the cyborg as a prosthetic relationship of humans and technology, which 'leaves largely intact those two categories– (human) body and technology—that preceded the conjunction' (2003: 323).

To approach subjects as constituted in contingent relationships with technology, Currier turns to the notion of 'assemblages' as 'functional conglomerations of elements' that are not the result of addition because 'the component elements are not understood as unified, stable, or self-identical' (Currier, 2002: 531).[16] Assemblages are emergent effects in 'forces and flows of components' that 'meet with and link to the forces and flows of other elements' (2002: 531). This idea entails a different notion of cause and effect from that employed in feminist constructivist technology studies, because 'a self-identical body or object does not exist as origin, prior to or outside the field of encounters that articulate it within any specific assemblage' (2002: 531). The relevance of this approach for breaking out of analyses that position men's gender identity as the cause of the masculinity of technology and technological work is obvious. It also has radical consequences for the understanding of identity, which 'does become peripheral: it is a by-product, which may appear within the operations of assembling' (Currier, 2003: 333).

Currier draws on Gilles Deleuze and Félix Guattari's (1987) critique of the modern subject.[17] They argue that subjectivity is not the expression of essence, hidden in human bodies, but an effect of actions performed in assemblages of several humans and non-humans. Brian Massumi interprets this to mean that human '"subjectivity" in the sense of personal thought or feeling is a special case existing only on one level of a dissipated human body system: the bounded, dominated level of the body as subjected group' (Massumi, 1992: 80).[18]

This view of subjects, subjectivity and identity as effects emerging from complex relationships also rejects the semiotic order of the heterosexual matrix. Humans, signified in the heterosexual matrix, are produced as autonomous, unified entities with identity traits, such as gender and sexuality, which determine their relationships with other humans and other elements in their environment. The notion of assemblage struggles against this 'semiotic subjugation'[19] by refusing to submit to a view of the subject as a stable entity with an inner core that determines its relationships with others. Assemblages are always in motion and cannot be kept stable in any semiotic grid. This human is a being in motion, an effect of many processes, not clearly delineated as outside and inside once and for all but always in a 'metastable assemblage'. Such 'metastable assemblages' cannot be the sites of fixed sexual, or gender, identities with determining functions.

'Assemblage' refigures subjectivity as constituted in complex relationships with technology, placing the relationship as the crucial mechanism, not identity. This indicates the direction in which feminist constructivist technology studies need to move in order to approach the desired objective of understanding the coproduction of gender and technology. It would enable analyses that do not commit to any particular understanding of what gender is, before investigating how it is produced in particular circumstances. However, the approach in itself points to description rather than critique[20] and abandoning gender as a fixed point that grounds critique can cause problems for feminists. From a feminist perspective Deleuze and Guattari's ideas 'seem no more attentive to questions of the specificity and particularity of women than psychoanalytic frameworks' (Grosz, 1994: 182). Their thinking displays 'little if any awareness of the masculinity of their pronouncements, of the sexual particularity of their own theoretical positions' (Grosz, 1994: 182). This problem also pertains to social constructivist approaches to technology; it surfaced in the meeting between this perspective and feminism in technology from the start, according to Gill and Grint (1995). Still, if the objective is to understand the coproduction of gender and technology, the critical analysis cannot assume a gendered subject as the starting point. Research that abandons gender as a fixed heteronormative binary needs another platform that enables critique. In the remainder of this paper I will discuss some possibilities suggested in feminist analyses drawing on queer theory.

QUEER BEYOND IDENTITY

Faced with the risk of losing the 'subject' of critique, the elaborations of 'nonhumanist' concepts by feminists inspired by queer theory can offer valuable ideas. Queer theory offers ways of critiquing power relations premised on sexuality and gender while rejecting the idea of the modern subject. Already from the outset, in the early 1990s, one formulation of queer aimed to move beyond identity, arguing that the point with this concept was not to 'confront the logic of heterosexuality by being another kind of identity' (Kennedy, 1994: 140).[21] In contrast to lesbian and gay politics that stabilize sexual identity, the impetus of queer is to 'disturb all sexual boundaries, and create sexual mayhem, so that any individual may occupy or perform any sexual or gender identity, rather than have a true identity; in this way, queer undermines the very notion of a truth of sexuality' (1994: 140). This articulation of queer encourages theorizing that moves beyond the critique of heteronormativity in a rejection of the modern subject. The anti-identity position also resonates with Currier's understanding of assemblages and it promotes conceptualizations of the human that do not rely on the idea of the modern subject to formulate criticisms of power asymmetries producing sexuality and gender in specific constellations.

In recent works philosopher Elizabeth Grosz demonstrates the potential of queer theory to take the discussion beyond the well-trodden paths of identity. She argues for a reorientation of feminist theory, claiming that its reliance on identity politics has imposed limitations by tending to 'understand identity as the synthesis of one's past (one is where one was born, what class, race, and sex one was born into, the events or history that constitute one's life) rather than a synthesis oriented to an open or indeterminable goal, a trajectory or direction' (Grosz, 2005: 213). In her view the temporality of identity politics is mistaken: '[O]ne's sexuality is contained in the *next* sexual encounter, rather than in the synthesis of all one's past sexual activities' (2005: 213, emphasis in original). In the context of technology studies such a temporal reorientation would put humans on an equal ontological footing with technology, which is already understood to be open to reformulation in relation to future encounters. Grosz further suggests that feminist theory needs to be conceived of as a 'struggle to render more mobile, fluid, and transformable the means by which the female subject is produced and represented' (2005: 193). Adopting this aim would be beneficial to the project of understanding the coproduction of gender and technology, since it would strive to 'mobilize and transform the position of women, the alignment of forces that constitute that "identity" and "position," that stratification which stabilizes itself as a place and an identity' (2005: 193). Empirical feminist studies of gender and technology need to be able to follow up on the constructivist claim that things could be otherwise; in order to do so they need theoretical frameworks that are open to the idea of 'a future in which forces align in ways fundamentally different from the past and present' (2005: 193). Feminist constructivist technology studies should not be satisfied with struggling for recognition 'by the others who occupy social dominant positions' (2005: 194). A doubly constructivist analysis that aims for change needs to move beyond the comfort zone of heteronormativity.

RE-READING GENDER IN TECHNOLOGICAL COMMUNITIES

To move from the abstractions of queer feminist philosophy to the critical analyses aimed for by ethnographers, a return to Elspeth Probyn's discussion of 'belonging' from the mid 1990s is useful. She proposes that 'instead of inquiring into the depths of sociality, let us consider the social world as surface' (Probyn, 1996: 19). This signals a departure from conventional social research that is looking for underlying causes of phenomena, thought to merely be expressed on the surface.

This initial idea in Probyn's book enables a re-reading of Kvande's representation of women engineers. Instead of understanding the studied engineers as expressing their femininity in ways calculated to fit the implicit rules of the workplace, a focus on the surface points in the direction of the interview situation. The designation of femininity as 'dressing in lace and frills' and being in total opposition to the engineering workplace invokes a very unrealistic stereotype. The quoted engineer constructs femininity as very different from anything that could be encountered in the workplace, consequently the latter will always be understood as masculine. This construction of gender is indicative of the heteronormative practice of keeping femininity and masculinity apart, even when women and men work together and do the same things. This statement can be read in relation to the particular situation: the interviewee assures the researcher that she knows how to do femininity and how to draw the boundaries for feminine conduct. The utterance produces multiple belongings—with a society that distinguishes sharply between femininity and masculinity as interior stable cores; with femininity as a project for women; and with the masculine norms of the workplace. The interviewee performs heteronormative gender verbally in a way that produces an interior that belongs with the feminine and an outside that fits in with the masculine workplace. Instead of reading this speech act as bearing witness to a stable but hidden identity, Probyn's approach suggests that it can be understood as a way of doing the interior/exterior distinction that is important for establishing subjectivity. The 'perplexity of living' is, in the few words quoted by Kvande, handled in a way that speaks to the 'desire for some sort of attachment, be it to other people, places, or modes of being, and the ways in which individuals and groups are caught within wanting to belong, wanting to become, a process that is fueled by yearning rather than the positing of identity as a stable state' (Probyn, 1996: 19).

Focussing on the surface and the situation at hand also facilitates a rethinking of the discrepancy between the gender differentiating talk and the observed conduct among the engineers studied by Kleif and Faulkner. Instead of interpreting this talk as expressing something nonlinguistic that precedes it, paying attention to the surface could mean looking at what it does. The talk performs the gender difference that heteronormativity requires, a difference that it is not possible to behaviourally enact as a software engineer who is committed to their work. As a productive force this talk produces belongings in the complex situation of the technical workplace.

Probyn further argues for the indeterminacy of relations and surface belongings: 'such forms of sociality, driven by desire, produce unexpected connections as they rub against each other, displaying on the surface their anteriority' (Probyn, 1996: 35). In relation to Vehviläinen's understanding of gender, a preparedness to notice unexpected, moving connections could have enabled links to studies of lesbians and technology, which could have opened new questions. An analysis open to 'unexpected connections' could ask in which ways desires for different belongings influence relations with technology. If an anterior desire to belong with other lesbians renders it unimportant to maintain a distance to technology, this needs to be paid serious attention because then heteronormativity is a force that disables a connection between many women and technology.

That 'surface belongings and desiring identities refuse to stand still' (Probyn, 1996: 35) is an argument that speaks to the way in which futures are produced. While the modern subject was a product explained by its past, the non-humanist perspective features the assemblage as moving towards the future. The human element of such 'post-human' subjects may be understood to aim towards connections with others. The complexity of forces that influence the actual movement of any assemblage makes it impossible to predict how these connections will occur, or what effects they will have. In such a conceptual framework the ways in which gender influences technology cannot be explained by looking at the past of the humans involved. If identity is an effect of connections made between surfaces that rub against each other the failure of DDS and New Topia, analysed by Oudshoorn, Rommes and Stienstra, needs to be thought of in relation to which belongings are produced at the different points of contact. What are the conditions for generating different assemblages incorporating this technology? Perhaps the perceived masculinity of the design style is constitutive to some gender identities but not to others. Different desires to connect with that which is culturally masculine may produce different belongings for assembled men and women, heterosexual and homosexual, constituted in this technological context.

This brief re-reading does not answer the question of coproduction, but it points to other ways of thinking that can generate new empirical questions and critical analyses. If gender is coproduced with technology it needs to be approached as emerging in between the elements assembling into subjects and objects. In this paper I have argued that feminist constructivist technology studies have, so far, not been able to capture this. The notion of assemblages, elaborated in order to capture the anti-deterministic constitution of subjects in relationships with technology, suggests ways to analyse gendered identity as produced in these relationships. Thinking of gendered subjectivity as an effect of assembling makes it possible to get away from the idea that identity is the only determinant for behaviour and experience. This would imply 'a shift of epistemological framework, where identity no longer functions as the ordering framework, but rather is itself a product of historical circumstance' (Currier, 2003: 333). Such a shift is what the present paper has argued for in claiming that the current analytical impasse in feminist constructivist technology studies requires a thorough rethinking of gender, away from the heteronormativity that stabilizes the subject as cause, toward a feminism that has surpassed gender as a deterministic binary. In turning to feminist elaborations of queer theory I argued that rejecting the modern subject as the anchor point does not have to lead to an abandonment of critique of power relations based on gender and sexuality. Instead it may offer ways of reconnecting empirical research among engineers and technology users with current feminist theorizing.

NOTES

1. See Judy Wajcman (2004) for a recent introduction to feminist technology studies, which she calls 'technofeminism'.
2. Wendy Faulkner (2001) uses the term 'feminist technology studies' for this sub-field to distinguish it from 'women and technology', in which technology is taken as a neutral given. The present notion of 'feminist constructivist technology studies' specifies this further to indicate feminist research within the field of science and technology studies. This sets them apart from feminist research on technology pursued in other subjects.
3. There are several different forms of constructivism in technology studies, drawing on different theoretical and philosophical frameworks (see Mackenzie and Wajcman, 1999 for an introduction). In feminist constructivist technology studies these differences tend to be less important since they all challenge the presumed autonomy and social neutrality of technology.
4. One radical approach is actor-network theory which argues that social theory is mistaken in assuming the existence of social structures, agency as a human property and subjectivity as a cause for actions and events (Latour, 1992). This approach demands that equal attention is paid to the ways in which technical artefacts exercise delegated agency, which would generate a different understanding of the social order as well as of the relationships between humans and the non-human. Other constructivist perspectives are considerably less categorical in their critique of social theory (cf. Pinch and Bijker, 1987).
5. The term 'production', used by Faulkner, marks a critical approach to the idea of closure, common in constructivist technology studies. Feminists argue that a technology in use is not permanently settled when it leaves the context of engineering; it is continuously being re-configured in relation to changing contexts of use and cultural interpretation. The present discussion does not address this aspect, hence, for terminological convenience the terms 'production' and 'construction' are used interchangeably.
6. Faulkner refers to Flis Henwood (1993) on this topic but does not elaborate further.
7. Halberstam's (1998) discussion of 'female masculinity' has nothing to do with workplace conduct, but the notion itself is illuminating because it links bodies and gender in ways less common. It is considerably more common to view all female conduct as feminine and to associate masculinity solely with men, like Kvande does in the article discussed. Halberstam's notion highlights that this is not a neutral practice but that it is based in heteronormativity and has consequences for Kvande's analysis.
8. The studies of lesbians and technology mentioned here do not assume a constructivist perspective, nor are they substantially referred to in feminist constructivist technology studies. I therefore regard them as outside of this field.
9. When lesbians appear in case study populations they seem to have closer relationships with technology, which gets mentioned as an aside or in the footnotes (see Rommes, 2002: 243, note 251 for an example).
10. Using the notion of 'the heterosexual matrix' in relation to the written representations of gender in feminist technology studies deviates from Butler's original intentions. In line with this deviation I will not engage with the extensive debate on the problems with this concept that have been thoroughly worked through in the 15 years since it was first introduced.
11. Butler explicitly mentions the work of Adrienne Rich and Monique Wittig as inspiration for the concept (1999: 194, note 6).
12. This interpretation of the heterosexual matrix is inspired by Monique Wittig's claim that:

    > Lesbian is the only concept I know of which is beyond the categories of sex (woman and man), because the designated subject (lesbian) is not a woman, either economically, or politically, or ideologically. For what makes a woman is a specific social relation to a man . . . which implies personal and physical obligation as well as economic obligation . . . a relation which lesbians escape by refusing to become or to stay heterosexual. (Wittig, 1992 [1980]: 20, emphasis in original)

13. Haraway also explicitly positions the cyborg as a figure outside the relationships of power captured in the notions of heteronormativity and the heterosexual matrix.
14. For example Faulkner points to the resonance between the constructivist insistence that technology is integral to the social fabric and Haraway's 'conceptualization of our cyborg-like existence' (Faulkner, 2001: 90) without further elaboration.

15. This is in spite of Haraway's own view that the concept still has much to offer (Haraway, 2000).
16. Another revision of the cyborg is undertaken by Zoë Sofoulis (2002) who turns to the 'actor-network hybrid' that shares with the cyborg an emphasis on the relational character of subjectivity and extends these relationships from the realm of the human to include non-humans.
17. Some feminist constructivist technology studies echo this perspective, via actor-network theory (ANT), informed by the same debates in French philosophy—for example, Ingunn Moser, who expresses an interest in the ' . . . complex ordering practices and enactments, to the hybrid collectives which make these practices and enactments possible, and to the agencies and subjectivities they enable' (Moser, 2003: 31). However, Moser does not elaborate on the relationship between feminism and ANT in the discussion of hybrid subjects. Her study develops a phenomenological understanding of hybrid subjectivity as individual experience and situated practices.
18. This resonates with one statement in Haraway's original articulation of 'the cyborg': 'Why should our bodies end at the skin, or include at best other beings encapsulated by skin?' (1991: 178). However, as pointed out by Currier, this aspect of the cyborg is not further developed in the original argument, and other statements appear to contradict it; hence, the cyborg can easily be read in a prosthetic sense.
19. Guattari's discussion of capitalist repression in terms of 'semiotic subjugation' can be adapted from the context of critique of capitalism into that of heteronormativity: 'Dominant power extends the semiotic subjugation of individuals unless the struggle is pursued on every front, particularly those of power formations. Most people don't even notice this semiotic subjugation, it's as though they do not want to believe it exists . . . ' (Guattari, 1996: 12).
20. In this it is similar to constructivism in technology studies and open to the same criticism levelled against the latter by feminists in the early 1990s (Cockburn, 1993).
21. Queer theory is far from a unified field. Noreen Giffney outlines the division between those who use it as 'another, shorthand name for lesbian and gay studies' (2004: 74) or as a way to 'expose *all* norms for the way they define, solidify, and defend their shaky self-identities by excluding those (dissident others) who fail or refuse to conform' (2004: 75, emphasis in original). The present paper favours the latter alternative.

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CHAPTER 24

Feminist Heterosexual Imaginaries of Reproduction: Lesbian Conception in Feminist Studies of Reproductive Technologies

Petra Nordqvist

INTRODUCTION

Lesbians increasingly seek to reproduce and over the past few decades a lesbian ‘baby boom’ has emerged (Agigian, 2004). Reproductive technologies and donated sperm constitute the starting point in lesbians’ processes of conception. Unlike heterosexual couples’ use of reproductive technologies as a corrective to failed conception through heterosexual intercourse, lesbian conception is from the outset disconnected from sex. Lesbians’ practices thus potentially disrupt the idea that conception must follow from, and intrinsically be related to, heterosexual intercourse. Considering such practices may therefore shed some light on how reproduction is constructed and represented when it involves reproductive technologies.

According to Agigian (2004: 7), lesbians and unmarried women in the US started to conceive using self-arranged donor conception in the 1970s. In the UK, self-arranged conception has become a common feature of lesbian reproductive practices over recent decades (Saffron, 1998). This is likely to be linked in part by the legal restrictions that have, until recently, denied lesbians access to British infertility clinics[1] (Barney, 2005; Lasker, 1998). With increased access, there is evidence that lesbians are increasingly using clinical fertility treatment to conceive.[2] Between the years 2000 and 2005, official data suggest that the proportion of lesbian couples who sought donor insemination treatment in UK clinics more than doubled, and in 2005 lesbians constituted 14.4 per cent of all clients seeking donor insemination in clinics as well as increasing proportions of IVF clients (Human Fertilisation and Embryology Authority, 2006).[3] Reproductive technologies, used in self-arranged donor insemination, clinical donor insemination and *in vitro* fertilization (IVF), can now be understood to have an established place in lesbian reproductive practices.[4]

Despite reproductive technologies commonly featuring in lesbian conception, surprisingly little is known about how lesbians experience reproductive technologies. A conventional literature search demonstrates a very limited number of studies. When searching electronically, adding the search terms ‘lesbian’ and ‘mother’ to ‘donor insemination’, ‘reproductive technology’ and ‘medical technology’ significantly lowered the recorded hits of studies (Table 24.1: recorded hits 1A–3B).

While it is important to note that the recorded hits are unlikely to include all relevant studies, the low hit rate provides evidence that, in a very material and real

Table 24.1 Recorded hit rates in literature search of donor insemination and lesbian conception

Search number	*Search part*	*Search term*	*Recorded hits*
1	A	(donor insemination)	322
	B	(lesbian*) and (mother*) and (donor insemination)	18
2	A	(reproductive technology)	2338
	B	(lesbian*) and (mother*) and (reproductive technology)	18
3	A	(medical technology)	1120
	B	(lesbian*) and (mother*) and (medical technology)	0

*Search results in combined search designed to identify literature on lesbian conception and reproductive technology in gateways Criminal Justice Abstracts, MEDLINE, PAIS International, Social Science Citation Index (ISI) on the Web of Knowledge, Sociological Abstracts, Web of Science (ISI) on the Web of Knowledge, University of York Library Catalogue. Search date 30 October 2006.

sense, lesbians are hardly recognized as reproductive agents within available research. To date, only a small body of research, predominantly from the UK and the USA, addresses lesbian conception (see for example Agigian, 2004; Chabot and Ames, 2004; Haimes and Weiner, 2000; Sullivan, 2004; Mamo, 2007).

How can we understand the marginal position of lesbians within research into reproduction and reproductive technologies when the empirical evidence shows that reproductive technologies have a well-established place in lesbian reproduction? In order to shed light on this paradox, I have reviewed feminist texts concerning reproductive technologies, considering these the most likely place to find research into lesbian reproduction. This article investigates how sexuality and lesbian reproduction is represented and constructed within such studies. 'Feminist' studies are defined as studies which are located within a theoretical framework that focuses on gender relations and reproductive practices, studies which are carried out by scholars who explicitly identify their work within a feminist tradition of research, or research which implicitly states an interest in how gender relations structure experiences of reproduction.

Across these studies, 'reproductive technologies' is used as a generic term in feminist literature researching technologies relating to conception and pregnancy (Edwards et al., 1999; McNeil, 1990; Stanworth, 1987a; Strathern, 1992; Taylor, 2000). The concept 'reproductive technology' has come to span technology used to control, promote and assist conception such as pre-implantation genetic diagnostics (PGD), donor insemination (DI), intrauterine insemination (IUI), *in vitro* fertilization (IVF), gamete intra-fallopian transfer (GIFT) and intra-cytoplasmic sperm injection (ICSI). The concept also refers to technologies that are used to monitor and screen women's pregnant bodies and foetuses, such as ultrasound and amniocentesis, which are becoming more routine for pregnant women (Taylor, 2000: 391).

There are some important distinctions to be made about the above technologies and the process of medicalization. Technologies such as PGD and IVF have been developed in a medical context and do not exist outside of it: they are only available in clinics, and are regulated and controlled in law. Donor insemination, on the other hand, can be performed both within and outside a clinical context. While clinical DI is regulated in law, self-arranged DI is not. Furthermore, it does not require sophisticated technology (Saffron, 1998: 65). The latter is likely to appeal widely to women who wish to conceive without heterosexual intercourse, and who do not necessarily experience infertility problems, but who cannot, or do not wish to, access clinical treatment (Lasker, 1998). Screening tests, existing within a medical context, are likely to apply to pregnant women regardless of sexual identity or context of their pregnancy.

This article is divided into four sections to explore the ways in which lesbian conception figures within feminist studies of reproductive technologies. As background to my review of these studies, I outline feminist and queer critical studies of heterosexuality, with a particular focus on the concept of 'the heterosexual imaginary', as introduced by Chrys Ingraham (1996). Drawing on Thompson (2002), a distinction is then made between what can be conceptualized as an early and a more recent phase within feminist studies of women and infertility, as outlined in sections two and three. Primarily, my interest in this distinction is in the difference between what Thompson identifies as a structuralist interest in stratification in earlier studies (1984–91) (Thompson, 2002: 53, 57), compared to more multiple understandings and a focus on 'the lived worlds of infertility' in more recent studies (1991–9) (Thompson, 2002: 53, 63). Potentially, the latter phase gives greater scope for lesbian conception to be recognized. It is therefore of specific interest to investigate how lesbian conception figures in such studies. In a fourth section, I offer an in-depth exploration of three influential pieces of ethnographic research from this period: Sarah Franklin's (1997) *Embodied Progress: A Cultural Account of Assisted Conception,* Charis Cussins' (now Thompson) (1998) 'Producing Reproduction: Techniques of Normalization and Naturalization in Infertility Clinics' (a version of this chapter was also published in Thompson, 2005) and Rayna Rapp's (1999) *Testing Women, Testing the Fetus: The Social Impact of Amniocentesis in America.* These studies focus on women's lived experiences of IVF, fertility treatment and amniocentesis. My reading illustrates in detail how reproduction is constructed and represented in studies aiming to account for lived experiences of reproductive technologies.

CRITICAL STUDIES OF HETEROSEXUALITY

The early writings of Adrienne Rich ([1980] 1993) and Monique Wittig ([1981] 1993) have proved highly influential as explorations of heterosexuality. Rich suggests that heterosexuality can be understood as a social force, which 'wrench[es] women's emotional and erotic energies away from themselves and other women and from woman-identified values' ([1980] 1993: 232). Wittig, developing a materialist feminist perspective, argues that the structures of heterosexuality are significant for how the category 'woman' is socially constructed ([1981] 1993).

The analysis of heterosexuality has since developed primarily through two distinct strands of thought: poststructuralist and materialist feminist. Poststructuralist readings of sexuality mainly draw on Foucauldian understandings of discourses, and emphasize cultural and linguistic constructions thereof. Notable is Judith Butler's theorization of a 'compulsory order of sex/gender/desire' (1990: 6), suggesting that heterosexuality is performative, and that performance produces heterosexuality as the *original* and homosexuality as the *copy.* Noteworthy is also the development of 'queer theory' which denotes multiple positions in a field in which cultural sexual categories and identities are understood as discursively constructed concepts that are transgressed by sexual practices (Fuss, 1991; for an overview see Adam, 2002). Materialist feminist perspectives, on the other hand, draw on earlier understandings of gender and sexuality as cultural and *social* categories, suggesting that sexual structures cannot be studied only on cultural and linguistic levels, but are also social and institutionalized phenomena (Ingraham, 1996; Jackson, 2001). Common to both is the analysis and critique of normative heterosexuality, closely intertwined with a binary construction of gender.

The developed concepts 'heteronormativity' and 'heterosexual imaginary' denote mechanisms in the operations of heterosexuality as a social structure. The concepts describe mechanisms of socially structured heterosexuality in slightly different ways and I shall therefore outline and draw on both concepts.

The term 'heteronormativity' has developed within studies of sexualities to denote how heterosexuality is produced as the *normal* sexual practice. According to Scott and Jackson (2006: 247), prevailing norms of heterosexuality can be understood as operating on multiple social levels. Jackson (2006) importantly notes that the concept of heteronormativity does not encompass the full complexity of different social dimensions of heterosexuality. I use 'heteronormativity' to describe the way in which heterosexuality is normatively constructed, both socially and culturally.

The term 'heterosexual imaginary' (Ingraham, 1996) was developed as a critique of unacknowledged and under-theorized heterosexuality in feminist sociology. Ingraham's 'heterosexual imaginary' refers to the way in which heterosexuality is normalized, and hence is considered to require neither exploration nor explanation (1996: 177). While gender has been deconstructed and analysed as a social construct in feminist sociology, heterosexuality remains 'the normal'. Ingraham states:

> The heterosexual imaginary is that way of thinking which conceals the operation of heterosexuality in structuring gender and closes off any critical analysis of heterosexuality as an organizing institution. The effect of this depiction is that heterosexuality circulates as taken for granted, naturally occurring, and unquestioned, while gender is understood as socially constructed and central to the organization of everyday life. (Ingraham, 1996: 169)

I draw on Ingraham's term 'the heterosexual imaginary' to refer to the process through which heterosexuality remains an unquestioned and 'naturalized' framework in some feminist work, a framework which seemingly renders unnecessary any analysis of how heterosexuality operates.

REPRESENTATIONS OF REPRODUCTION IN EARLY FEMINIST STUDIES OF REPRODUCTIVE TECHNOLOGIES

The forming of 'The Feminist International Network of Resistance to Reproductive and Genetic Engineering' (FINRRAGE), and its criticism of the impact of technology and medicine on women, can be seen as indicative of early feminist writings and engagement with what was conceptualized as the medicalization of reproduction (Henwood, 2001; Wajcman, 1991). FINRRAGE was initiated in 1984 and explicitly condemned reproductive technologies, viewing them as opposed to women's *natural* experiences of conception and childbirth. In a resolution, FINRRAGE states:

> We . . . declare that the female body, with its unique capacity for creating human life, is being expropriated and dissected as raw material for the technological production of human beings. ('Resolution from the FINRRAGE Conference', 1987)

Few of the early writings suggested that there would be a need to investigate the understandings and experiences of women who themselves undergo fertility treatment (however, see for example the exception of Stanworth, 1987a). Instead, studies, predominantly carried out within sociology and politics mainly in Britain, Europe and North America, took a structural perspective, indicating that natural procreation is polluted by medical and technological intervention:

> The potential of . . . technology to disconnect the foetus from a woman's body is seen as a specific form of the ancient masculine impulse 'to confine and limit and curb the creativity and potentially polluting power of female procreation'. (Oakley, 1976, quoted in Wajcman, 1991: 59)

In the late 1980s, three anthologies, those of Spallone and Steinberg (1987), Stanworth (1987b) and McNeil et al. (1990), presented essays which critiqued the development of reproductive technologies. Technologies were represented as conflicting with women's reproductive interests in earlier studies (see, for example, Steinberg, 1990; Oakley, 1987). Burfoot (1990), engaging with the process of IVF normalization, stated:

> Women need to be aware of the extent to which IVF has become normalised as a field in reproductive medicine and to realise that the high commercial gains at stake in IVF's development and dissemination are likely to prevail against a women-centered approach to infertility and reproduction. (Burfoot, 1990: 72)

Burfoot understood a 'women-centered' approach to pregnancy and reproduction as distinct from technological interventions and commercialism. A second example is that of Crowe (1990), who discussed the results of the *Warnock Report* and the influence of scientific knowledge on the discussion of 'embryo research':

> I . . . consider how the perception of IVF as being a medical/scientific concern, introduced as a 'treatment for infertility', makes it possible for its practitioners to become the arbiters of values and standards relating to women's reproduction and motherhood. (Crowe, 1990: 28)

Crowe argued that the dominance of medical/scientific knowledge of embryo research makes women's bodies and perspectives invisible in the process of reproduction. A critical reading of the way in which women and reproduction are situated in relation to such technologies is echoed in strands of some later studies:

> The implementation of advanced techniques of antenatal screening and foetal diagnosis in maternity care is underpinned by the rationales of control and experimentation. (Helén, 2004: 30)

Reproductive technology was, in earlier studies, identified within a medical framework and a biomedical discourse of reproduction. Consequently, non-medical reproductive technologies were *conceptually* excluded. This exclusion was evident partly in the theoretical interest taken in the technologies, and partly in the construction of reproductive technologies as medical. While I would not wish to reject either the idea that many reproductive technologies are developed in relation to the medicalization of reproduction and therefore only exist within a medical context, or that a process of medicalization has impacted upon the regulation and exclusion of lesbians from accessing clinical treatment, the *generic* conceptualization of such technologies as medical concealed alternative, non-medical practices of conception. From the perspective of lesbian conception, the major distinction between conceiving in a clinic or through self-arranged conception is not necessarily whether a technology is *medically* assisted. Rather, the different *effects* of self-arranged conception and clinical treatment are likely to matter: only clinical treatment enables effective health-screenings of the sperm and a legally controlled involvement of the sperm donor. Lesbians' varying use of forms of DI is bypassed when technology is identified as medical.

Furthermore, a distinction was made between 'nature' and 'technology', and 'natural' and 'artificial', in earlier writings. Haraway's (1991) 'A Cyborg Manifesto', first published in 1985, and her now widespread notion of the 'cyborg' and critique of a dichotomous understanding of nature and technology, did not at that time appear to influence the feminist studies discussed. Making a distinction between nature and technology had specific implications for the understanding of different methods of conception. In studies such as that of FINRRAGE, 'nature' was implicitly and intimately intertwined with understandings of pregnancy as a 'natural' event. Nature was defined outside of and separate from the technology realm. This representation entailed specific, but unacknowledged, assumptions about heterosexuality: heterosexual reproduction was represented as the non-technical, 'natural' method of conception and other methods, such as DI or IVF, were defined as technological and therefore 'unnatural'. In this way, lesbian reproduction, which from the outset is likely to involve technological features, was implicitly positioned in the realm of the 'unnatural'. Feminist condemnation of the reproductive technologies has the effect of creating a hierarchy between 'good' natural reproduction and 'bad' technologically assisted reproduction.

Although some voices were raised early on, declaring the potential subversiveness of reproductive technologies (see for example Firestone, [1970] 1997: 25), earlier feminist writings constructed technology as patriarchal control over women's bodies and as a tool of oppression. As Thompson (2002) indicates, such a perspective obscures any understanding of technology as carrying different meanings for different women. Assisted conception such as DI, which enables lesbian couples and single women to conceive, for example, can be understood as reducing rather than increasing patriarchal control over women's reproduction. Haimes and Weiner (2000: 478) demonstrate that donor insemination used within the context of a lesbian relationship can be experienced as a positive opportunity to conceive rather than as an unwished result of unsuccessful 'sexual' conception.

Early feminist studies further identified 'women' in the process of reproduction as the body which reproductive technologies act on and change, that is, the pregnant body. Women who occupy other positions in the reproductive processes, for example women who experience conception from the position of being the partner of a pregnant woman, are unrecognized. I do not wish to imply that the bodily experience of a woman undergoing fertility treatment or pregnancy is the same as a partner who supports her through the process; however, the equating of 'woman' with 'pregnant woman' is heterosexually normative. It obscures a central feature of lesbian couples' reproduction: a woman may take part in the process and experience of reproduction without being pregnant.

REPRODUCTIVE TECHNOLOGY, WOMEN'S AGENCY AND LESBIAN CONCEPTION

More recent feminist studies of reproductive technologies suggest not only that women may experience reproductive technology as an extension of patriarchy, but that reproductive technologies also can provide women with reproductive control (Thompson, 2002). Thus, it is argued, explorations of reproductive technologies need to consider women's agency in negotiating the role that reproductive technologies play in their lives (Henwood, 2001; Thompson, 2002).

Like earlier studies, more recent research into reproductive technologies is contextually specific. The main body of research is produced within the USA, Britain and Australia, as well as in Western European countries such as Finland and the Netherlands.[5] There is an increasing interest within the social sciences and humanities in how reproductive technologies are experienced and made sense of: studies are being undertaken within psychology, science and technology studies (STS), sociology, anthropology, gender studies, legal studies and health studies. More recent studies investigate a range of different technologies; for example pre-implantation genetic diagnostics (Roberts and Franklin, 2004), IVF (Franklin, 1997), surrogacy and egg donation (Ragoné, 1998; Thompson, 2001, 2005), donor insemination (Haimes, 1992; Lasker, 1998), amniocentesis (Rapp, 1999; Helén, 2004; Rothman, 1994), and ultrasound and visual technology (Taylor, 2000). This is by no means an exhaustive list, but represents a sample of the range of studies that investigate how different technologies are experienced.

More recent studies focus on the experience of a particular technology and the characteristics of such technology, for example IVF. The regulations governing access to the technologies therefore restricted the social composition and the participants invited to take part in these studies. Franklin (1997), studying IVF, states in her methodological account:

> All [participants] were white, married and in their mid-thirties to mid-forties. . . . Although marriage is not a requirement for access to IVF, the medical director of the clinic has strong views about the naturalness of the reproductive drive, and it is likely that unmarried or non-heterosexual women would not have felt welcome[.] (Franklin, 1997: 80f.)

As indicated by Franklin, the method of sampling through a fertility clinic is likely to direct the sample composition towards heterosexual couples since single women and lesbian couples have limited access. Peterson (2005) confirms that this is the case both in the UK and internationally. It is not unexpected therefore that studies draw on the experiences of heterosexual women and couples (see, for example, Thompson, 2001; Ragoné, 1998; Ulrich and Weatherall, 2000). One exception to this is Parry (2005), who researches thirty married women and two lesbians' understandings of 'family' in relation to their experiences of infertility.

The sample composition in studies of medical reproductive technologies indicates that structures of heterosexuality are foundational to access to technologies. It might therefore be expected that an appreciation of the dominance of heterosexuality would inform the research and that sexuality, as a mode of analysis, would be likely to be intrinsic to the studies. Heterosexuality, however, does not constitute a focus of analysis in theoretical accounts. Rather, the heterosexual couple constitute the taken for granted unit of reproductive technologies. For example, Strathern (1992, 1995) theorizes the fragmentation of motherhood and fatherhood in heterosexual couples' use of assisted fertilization:

> [T]he substance that makes a 'biological father' is not what makes a 'biological mother'. So while the biological (genetic) father is invariably referred to as a 'father' . . . that person is not necessarily held to be a parent: there is uncertainty about what relationship the act of donation as such creates . . . Thus we have two types of parent and, potentially at least, two types of parenthood. (Strathern, 1992: 149, 150)

Haimes (1992) investigates family normality in the debate about genetic parenthood and gamete donation, using a theoretical framework of heterosexual couples' reproduction, and Sandelowski and de Lacey (2002) investigate how the term 'patient' takes the meaning of 'couple' in infertility treatment of heterosexual couples. A heterosexual framework of study is therefore not only a consequence of the recruitment of heterosexual participants; it is reproduced in theoretical explorations of reproductive technologies. The heterosexual normativity evident in policy regulations of access to clinical treatment is also reproduced in studies thereof. That reproductive technologies and infertility treatment are predominantly researched from a heterosexual perspective is also evident when a broader range of feminist studies were examined (for example, see Helén, 2004; Kornelsen, 2005; Taylor, 2000; van der Plog, 2004).

ACCOUNTING FOR TECHNOLOGIES, CONSTRUCTING HETEROSEXUALITY

It appears that structures of heterosexuality shape who is invited to take part in studies of reproductive technologies and, more surprisingly, are taken for granted and unquestioned in the theoretical accounts produced from these studies. Against this backdrop, I move on to consider three influential pieces of research, those of Franklin (1997), Cussins (1998) and Rapp (1999), to investigate in more detail the mechanisms through which technologies, conception and sexuality are constructed.

Importantly, these pieces of research focus on different technologies. While Franklin (1997) focuses on the lived experience of IVF and Cussins (1998) on the culture of infertility clinics, Rapp (1999) studies the experiences of undergoing the pregnancy screening test amniocentesis. All studies focus on medically assisted technologies, but they are different in scope, process of implementation and intended outcome. The studies investigate technologies used at different stages in a cycle of achieving conception and experiencing pregnancy, and therefore illustrate how conception, technology and sexuality are constructed, and lesbian procreation represented, at different stages of reproduction.

ACCOUNTING FOR IVF

Franklin (1997) provides a cultural account of IVF in relation to understandings of conception as a 'fact of life'. Drawing on, and engaging with, 20th-century anthropologists, she suggests that in a Euro-American context conception as 'a fact of life' is a dominant cultural perception. Anthropological accounts of the 'facts of life' traditionally position conception and kinship as 'biological' and therefore 'natural' (pp. 21ff.). Franklin suggests that an idea of conception as 'biology' and a 'fact of life' is challenged by the experience of those undergoing IVF treatment. Here, the 'facts of life' (as culture defines them) fail to produce a 'successful' conception (p. 199).

In a multifaceted and detailed way, Franklin demonstrates how nature and technology in the context of IVF are constructed interchangeably. The lived experience of IVF is regarded as 'natural' at the same time as 'natural' conception is regarded as a 'miracle' (p. 188). Franklin (pp. 187, 209) suggests that biology is interpreted, by couples as well as clinicians, in technological terms and technology, in turn, is experienced as 'natural' and understood to provide what 'nature' cannot deliver:

> . . . 'nature' and 'technology' in the context of IVF are not only commensurate, but substitutable. Just as IVF clinicians 'learn' from nature how to improve their techniques, so 'nature' can be improved by scientific and technological assistance. (Franklin, 1997: 209)

What is 'new' about IVF, according to Franklin, is how science and technology become conflated with nature, and thereby contradict and challenge the cultural assumptions of procreation as a 'fact of life'.

Franklin's analysis of a fusion of 'nature' and 'technology' is based upon, and constructed alongside, heterosexual couples' non-technological conceptions as 'natural' ones. The theoretical framework of procreation as 'a fact of life' narrows the scope of the *study, life* and *coupledom* to heterosexual married couples. Conception was never 'a fact of life' for gays and lesbians. Franklin does not consider how, for example, IVF may be differently experienced by lesbian couples. Lesbians are not likely to conceptualize or experience IVF as a consequence of 'unsuccessful' lesbian sex, but rather as a consequence of unsuccessful attempts to conceive with donor insemination, thus challenging the theoretical perspective of conception as a 'fact of life'. In Franklin's study, heterosexual intercourse is not examined as a *method* of conception but is implicitly depicted as the 'natural' method of conception. In the context of the lesbian couple, heterosexual intercourse is not necessarily imagined and constructed as the 'natural' way to conceive, in general terms or for the couple. It appears that Franklin's theoretical interest implicitly places conception outside of heterosexual relationships.

Franklin's sample consists of heterosexual married couples (pp. 80–1). Her data appear to suggest that this is significant for the way in which IVF is conceptualized. According to Franklin (p. 138), women think about IVF treatment as a way to resolve childlessness and, thereby, an 'incomplete marriage':

> [T]he idea of 'completing' a marriage by having children has many components: raising children together as an extension of the relationship between husband and wife; having worked hard to achieve a level of financial security by which to offer children 'a good home'; belonging to an extended family by participating in the activities of childrearing; the desire to share an activity not defined by the demands of paid, professional work; and, simply, feeling that having children is part of the natural and normal progression of married life, some would say, even its purpose. (Franklin, 1997: 139)

Having the husband's support during treatment is also, according to Franklin, essential for the women undergoing treatment:

> Almost without exception, though often with a qualifier such as 'men feel things differently', women praised their husbands' supportiveness during treatment. (Franklin, 1997: 140)

It appears that the experience of the process of IVF is highly mediated through the status of being a heterosexual married couple. Sexuality as a *mode of analysis*, however, does not figure in Franklin's work. Such a perspective would clarify how experiences of IVF relate to what can be understood as specifically *heterosexual* life expectancies and gender relations. Using a sample of lesbian couples would possibly change the way in which using IVF is understood and experienced. For example, childlessness is not necessarily thought of as indicative of a failed lesbian relationship. In fact, lesbians who conceive and reproduce destabilize the norm; lesbian conception goes *against* cultural assumptions about reproduction. It also goes against assumptions about lesbian life (Lewin, 1993). Franklin does not investigate how heterosexual married couples may experience this in specific ways *because* they are heterosexual and married and how being married shapes understandings of what IVF *means*.[6]

I would suggest that both in terms of the theoretical insights and in terms of the study population from which the insights were generated, structures of sexuality influenced Franklin's analysis. Franklin imagines reproduction in a framework in which heterosexuality requires neither explanation nor analysis. Gay and lesbian life and conception are excluded by study definition, anthropological interest and theoretical outcome.

REPRODUCTION IN INFERTILITY CLINICS

Cussins (1998) explores the cultural and social construction of reproduction in infertility clinics. Studying two American clinics, she argues that what is considered normal within the infertility clinic is supported and confirmed by what is considered natural. Cussins (p. 67) suggests that heterosexuality is essential in this respect: considering heterosexuality to be 'natural' produces in the clinic notions of what is considered 'normal'. Heterosexual couples do not need to be married; heterosexuality alone is considered foundational for understanding a couple's wish to conceive as 'natural'. Following on from this construction, heterosexual couples are granted access to treatment:

> [A] mother-and-father family is normative for the clinics because it is assumed to be a natural state of affairs, so clinics do not need to invoke the 'social' convention of marriage in selecting their patient couples[.] (Cussins, 1998: 67)

Heterosexuality, Cussins suggests, is considered an essential criterion to provide a stable, and therefore good, family. The sperm bank of the clinic can be used by heterosexual couples but lesbian couples and single women are denied access (p. 72).

Cussins thus indicates that structures of heterosexuality permeate fertility treatment in clinics at a level of access. At a deeper level of analysis, however, the function of heterosexuality remains unproblematized. In a discussion of the feminization of infertility treatment, Cussins states:

> Epidemiological statistics suggest that the male partner is implicated in at least 50 percent of infertility cases worldwide. Yet it is women who take most of the drugs and undergo most of the ultrasounds, hysterosalpingograms, surgery, and other invasive procedures . . . [T]reatment has a number of paradoxical effects: 'couple' becomes, almost exclusively, the female partner[.] (Cussins, 1998: 75)

In her demonstration of how treatment of 'the female partner' is related to the minimal treatment of 'the male partner', Cussins implicitly positions the reproductive process within a heterosexual framework of procreation. While lesbians are likely to experience a similar medical focus on the partner who will carry the child, the heterosexual gender relations that Cussins describes are unlikely to be played out in a conception that involves two women as reproductive partners and a sperm donor.

Further examples of unproblematized heterosexuality in Cussins' work can be found in her analysis of how the clinic is spatially structured. In an account of the organization of privacy for male masturbation, Cussins states:

> If possible, the examination room furthest away from the nurses' station is assigned for male patients to collect [sperm]. It is out of the line of sight of any of the offices. . . . When [the technicians] hear the door open, they move to the door of their room, to make sure that the man can hand his container straight to somebody who will deal with it technically. The transmission from private and sexual to an appropriate clinical object is thus smoothly assured. (Cussins, 1998: 90)

The way in which private and public are separated in the clinic and shape the work of the clinicians appears to be structured around ideas of heterosexual sex and procreation as a sexual activity that needs 'organizing' in a clinical setting. The data suggest that the careful set-up for male masturbation is structured to mark and emphasize boundaries between private sexuality and clinical conception in a public setting, and thereby implicitly construct a conceptual link between, on the one hand, conception via heterosexual intercourse and, on the other, conception via IVF. That these practices are specifically heterosexual, however, remains unacknowledged by Cussins. In comparison, a clinic organized to treat lesbians and/or single women may be unlikely to invoke ideas of private sexuality in relation to clinical procreation, since these procreations are not necessarily coupled with sexual activity *in the first place.* Regulations governing donor anonymity make it likely, furthermore, that clinical space involving sperm donations would be organized so that couples and donors were kept separate.

The blatant display of heterosexuality in 'women's' magazines in the waiting room area, and magazines of the '*Playboy*-type' hidden in drawers in the male masturbation room (p. 90), can be understood as objects shaped by and displayed according to heterosexual gender relations. It is possible, for example, that an IVF clinic open to gay donors and lesbian patients would display other magazines in the waiting room and in the masturbation room. Sexuality used as a mode of analysis could clarify the role of such objects in a clinic. While Cussins' data appear to suggest that understandings and organizations of sexuality and conception in the clinic are inherently, and specifically, heterosexual, she does not significantly interrogate her empirical material from a perspective of sexuality.

THE CULTURAL ORGANIZATION OF AMNIOCENTESIS

Rapp (1999) researches women's experiences of amniocentesis, a genetic medical test of the amniotic fluid during pregnancy, in relation to how gendered divisions of private and public spheres map onto the social management of genetic testing. Included in her study are women who experience genetic testing. Rapp states:

> Through observations of PDL [Prenatal Diagnostic Laboratory] intake patient interviews, I also began to recruit a sample of women who were having amniocentesis and were willing to be interviewed at home (ideally, during the long weeks of waiting for tests results). I initially attempted to conduct interviews with the partners and other close supporters of this patient population, but this proved a difficult task; I was able to interview only fifteen men (or FOFs, fathers of fetuses, as I came to think of them), compared to more than eighty women. (Rapp, 1999: 6)

Rapp outlines how she intended to include partners and supporters of pregnant women, but that this failed as she only managed to recruit a small number of men, thus implicitly identifying her sample as heterosexual. Rapp describes how she included a diverse sample in terms of social class and ethnicity in order to reflect how class and ethnic background shape different understandings of amniocentesis (p. 9). However, whether lesbians or lesbian couples were included in the sample is unclear. Reading the research in more detail, I would suggest that lesbians are excluded not only in the sampling process, but also in the normative assumption of heterosexual procreation constructed in her account.

Rapp (pp. 5, 49) explores the complexities and contradictions in the social impact of a reproductive technology, and suggests that women become 'moral pioneers' when involved in the practice of amniocentesis: women are made to choose who should be born and who should not according to ideas of normalcy and quality in human genes:

> [I] came to think of the women who submitted to the discipline of a new reproductive technology in order to reap its biomedical benefits as moral pioneers. At once conscripts to technoscientific regimes of quality control and normalization, and explorers of

> the ethical territory its presence produces, contemporary pregnant women have become our moral philosophers of the private. (Rapp, 1999: 306)

In her argument, Rapp shifts between, and equates, a conceptualization of 'women' with 'pregnant women'. As the quote above signals, Rapp positions 'women' who come into contact with and experience reproductive technology as 'pregnant'. In so doing, Rapp thus implicitly endorses the normative assumptions that women who experience reproductive technologies are pregnant. It is an assumption which denies a place in the clinic, and in her analysis, for women who experience reproductive technologies as partners of other women.

The exclusion of women who reproduce outside of a heterosexual couple is again evident in Rapp's discussion of gender relations. Rapp suggests that pregnancy and amniocentesis exist within a complex context of heterosexual gender-related negotiations, domination and resistance:

> [I] do not believe that a woman's decision to use or refuse prenatal testing is simply driven by the power of her partner's wishes. Rather, the very fact of decision-making in a couple involved in amniocentesis reveals the existing gender negotiations within which a specific pregnancy is undertaken. (Rapp, 1999: 100)

While this quote might suggest a use of 'partner' as a gender-neutral term, a close reading demonstrates that Rapp uses the terms 'partner' and 'husband' interchangeably in the section (pp. 99–100). Rapp thus explicitly and implicitly positions the users of genetic counselling and testing within a heterosexual familial and reproductive context. While gender is at the forefront of Rapp's analysis of amniocentesis, sexuality is invisible as a mode of analysis. The subtle slide between 'woman' and 'pregnant woman' to 'heterosexual pregnant woman' normalizes and reproduces a notion of procreation as a heterosexual activity, and excludes an investigation of how structures of heterosexuality shape amniocentesis.

As in the other exemplar texts that I have examined, lesbian conception is rendered theoretically invisible in Rapp's study and cannot easily be 'added in'. In her study, there is no conceptual or empirical place for a woman who is expecting to become a mother, but who is not pregnant. A lesbian couple undergoing amniocentesis, where one woman carries a child and the other will be its parent but does not have a biogenetic relation to it, opens up questions about genetic parenthood beyond the parental unit. Lesbians' experiences of amniocentesis are also likely to be shaped by the risk of encountering homophobic attitudes among staff (see, for example, McManus et al., 2006). Sexualities are therefore likely to have an impact on experiences of pregnancy-related health care. Focused on heterosexual women's experiences, Rapp's analysis does not easily encompass the procreation of lesbians.

CONCLUDING REMARKS

Reproductive technologies now have an established place in lesbian reproductive practices. This article set out to investigate how lesbian conception figures within feminist research into reproductive technologies. The exploration indicates that lesbian reproduction is absent both within early feminist research into reproductive technologies and, more surprisingly, within more recent feminist studies. I have suggested that this absence relates to the heterosexually normative assumptions permeating studies on analytical and theoretical levels.

I have argued that heterosexuality is a foundational feature of and normative assumption within both early and more recent feminist studies of reproductive technologies. The absence of an analysis of sexuality should not be taken to imply that structures of sexualities do not shape the use, experiences of, and research into reproductive technologies. Rather, I would like to suggest, heterosexuality constitutes a foundational perspective which permeates and shapes feminist procreative imaginaries. But while heterosexuality strongly influences the studies, sexuality as a *mode of analysis* is neglected and under-theorized. Other practices and experiences, such as those of lesbians, are excluded at the same time as the need for an analysis of heterosexuality is closed off (Ingraham, 1996: 169). Despite the potential uncoupling of sex and reproduction in the use of reproductive technologies, as highlighted by lesbian conception, it appears that conception is recreated and represented as heterosexual in feminist studies of reproductive technologies.

Furthermore, the ways in which a heterosexual imaginary manifests itself and is normalized in both early and more recent studies are also the reason why lesbian reproduction cannot simply be 'added' into feminist research into reproductive technologies. Lesbians' use of multiple non-medical and medical technologies in their route to conception challenges theoretical frameworks developed within feminist studies. For example, lesbian conception challenges assumptions that IVF is (always) a consequence of 'unsuccessful' heterosexual intercourse and it problematizes a theoretical framework of conception as a 'fact of life'. Furthermore, issues concerning finding, choosing and relating to a sperm donor are likely to be a central feature of any lesbian conception (Chabot and Ames, 2004), but do not figure in these feminist studies. The potential stigma associated with being lesbian is also likely to permeate experiences of health care and require a critique of the heteronormative theoretical frameworks on which feminist research appears largely to be based. Lesbian conception cannot easily be 'added into' existing feminist theoretical frameworks *because* it clashes with normative assumptions of conception.

In contrast to Thompson's (2002) findings of a distinct shift in theoretical approaches in early and more recent feminist research, my analysis points to important continuities between early and more recent feminist studies of reproductive technologies. Both normalize heterosexuality, and render it at the same time fundamental and yet theoretically insignificant. Lesbians are not identified as reproductive agents—culturally, socially or politically. Despite the fact that technologies have an established place in lesbian reproductive practices, lesbians are continuously positioned as reproductive outsiders in feminist procreative imaginaries of reproductive technologies.

NOTES

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1. Lesbian couples' access to fertility treatment in the UK National Health Service is currently under review (Department of Health, 2006).
2. In the Human Fertilisation and Embryology Authority 2006 data, the category 'lesbian women' refers to women who have sought treatment together with a female partner. The category 'single women' refers to women who do not register with a partner. It is worth noting that these categories may not reflect the sexual identity of these women, or the relationship context in which they seek treatment. It is for example possible that childbearing partners in lesbian couples in some cases register as 'single women' given that lesbians have been denied access to treatment in clinics (Lasker, 1998).
3. The Human Fertilisation and Embryology Authority 2006 data indicate that lesbian couples constituted 6.7 per cent (N = 411) of all couples

who sought donor insemination treatment in clinics in the year 2000. By 2005, the proportion of lesbian donor insemination clients had increased to 14.4 per cent (N = 766). Furthermore, an increase in lesbian couples' use of IVF treatment has been demonstrated. In 2008, lesbian couples are said to constitute 0.5 per cent of all women receiving IVF treatment (Edemariam, 2008).

4. Politics of reproduction rely heavily on the construction of sexual categories, which in material and discursive ways structure experiences of reproduction. It should be noted that these sexual categories are, however, not unproblematic. Categories of sexuality can be understood as constructed and mobilized in politics of reproduction, for example with regards to access to fertility treatment (Bryld, 2001), rather than being merely 'reflected' in policies. However, because sexual categories are highly influential of experiences of conception, sexual practices can be understood to shape lived experiences, which is why such categorizations are still valid.
5. Van Balen and Inhorn (2002: 6) indicate that there is a Western domination in research into reproductive technologies and infertility, resulting in biased understandings of technologies.
6. Notably, same sex couples could not enter marriage or any other legally recognized partnership in the UK at the time of Franklin's study. This highlights how imagining IVF as a corrective of a childless (failed) marriage is specifically heterosexual.

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CHAPTER 25

From Reproductive Work to Regenerative Labour: The Female Body and the Stem Cell Industries

Catherine Waldby and Melinda Cooper

The identification and valorization of unacknowledged, feminized forms of economic productivity has been an important task for feminist theory. Since the 1960s, feminists have tried to expand existing notions of labour in order to encompass activities quite at odds with the industrial model of mass manufacture and the capital/labour relationship that defined economic productivity throughout most of the 20th century. During the 1970s and early 1980s, socialist feminists tried to rethink women's domesticity and maternal care as a form of reproductive labour, which complemented the industrial labour of the male breadwinner (Barrett, 1980; Delphy, 1984). More recently, feminists have played a central role in rethinking labour as the post-Fordist restructuring of economies has moved the productive emphasis away from industrial manufacture and towards the service and financial sectors, knowledge production and the culture industries. These are forms of productivity whose output is no longer the stable, mass-manufactured commodity, but rather less easily specified entities—entertainment and celebrity, intellectual property, customer satisfaction, future value, communicative exchange. The industrial model of labour as machinic potential (Walker, 2007), operationalized through the efficient ordering of tasks, no longer explains the activity of most employees in the first world economies. Here, Arlie Hochschild's work on emotional labour[1] (Hochschild, 1983) was the first study to come to grips with the ways feminized skills in the production of sociality and the pleasing of others were being transformed into essential forms of labour in the new economy. Since then terms like 'care labour' (Fisher and Tronto, 1990; Duffy, 2005) or 'affective labour' (Weeks, 2007) have proliferated to designate spheres of work that are generally feminized, and involve the nurturing of others—from the expansion of nursing work to the growth in corporate childcare and the food service industries.

In this article, we also propose to expand and rethink existing concepts of labour, in order to bring to light the essential economic role of women in an emerging productive sector. We refer to the stem cell and regenerative medicine industries, new fields of biomedical research that are rapidly expanding throughout the developed and some developing economies—the UK, North America, Western Europe but also India and China. Women constitute the primary tissue donors in the new stem cell industries, which require high volumes of human embryos, oöcytes, foetal tissue and umbilical cord blood. These industries rely on the maternal-embryonic nexus as a generative site, diverting material that might otherwise be used in attempts to generate new children towards the regeneration of existing bodies through stem cell therapies. The procurement of this material involves onerous forms of donation, requiring variously super ovulation, *in vitro* fertilization (IVF), pregnancy termination or birthing to disentangle it from the maternal body. Nevertheless it is generally given for free in the advanced industrial democracies, constituted as a surplus ('spare' embryos) or waste (umbilical cord 'afterbirth', cadaveric foetuses, poor quality oöcytes) whose generative powers should not be withheld from others.[2] Here, female bodily productivity is mobilized to support bioeconomic research, yet this economic value remains largely unacknowledged (Dickenson, 2007). At the same time, among impoverished female populations in developing nations, such biological material is now often procured through frankly transactional relations, where women undertake risky procedures for small fees. Women in South and East Asia, and Eastern Europe, can supplement their income through super ovulation and oöcyte vending, or negotiate free IVF treatment in exchange for embryos 'donated' for stem cell research (Waldby, 2008; Bharadwaj and Glasner, 2009).

In this article, we consider the centrality of female productive agency in the stem cell industries and investigate the rapid transformations in both the regulated and unregulated procurement of women's biological material. In particular we recast the gift economy for such material as a form of unacknowledged productive work. These labour relations become much more explicit in developing nations where the relative lack of bioethical regulation and the availability of impoverished female populations have permitted the procurement of high volumes of reproductive material in exchange for low fees.[3] However, in order to fully conceptualize feminized productivity in the bioeconomy, we move beyond the global political economy of procurement and open out the ideas of both feminized labour and female reproductive biology to critical scrutiny. Hence, we consider how historical transformations in the regulation of feminized labour *and* the technical repertoires of stem cell research renegotiate the productivity limits of female reproductive biology, opening it out to novel and profitable forms of surplus value and enrolling particular groups of women in complex negotiations over their role in bioeconomic activity.

FEMALE REPRODUCTIVE BIOLOGY AND REGENERATIVE MEDICINE

Regenerative medicine is a blanket term that brings together a number of different biological and biomedical disciplines to treat clinical conditions like cardiac damage, osteoporosis, diabetes and spinal cord injury, conditions associated with damaged tissues. The regenerative medicine methodology is still highly speculative, but its aim is to promote *in vivo* tissue regeneration, rather than relying on donated organs, by either stimulating the patient's own tissues or transplanted stem cell tissue. It is the latter approach that interests us here.

Stem cells are undifferentiated cells that can both renew themselves and give rise to one or more specialized cell types with specific functions in the body. The most celebrated type of stem cell is 'pluripotent', meaning that it has the capacity to develop into almost all of the body's tissue types. Recent research suggests that it may be possible to produce large numbers of pluripotent stem cells that differentiate on demand, providing an unlimited supply of transplantable tissue (Thomson, 1998). The major source of pluripotent stem cells is *in vitro* embryos. However, other types of reproductive tissues are also rich sources of stem cells. Umbilical cord blood, harvested at birth, has high concentrations of haematopoietic (blood producing) stem cells. Cord blood stem cells are capable of regenerating the entire blood system in patients with severe blood disorders, and their proponents claim that they have the potential for other kinds of regenerative action as well, for assisting in cardiac repair for example (Brown and Kraft, 2006). Foetal tissues harvested from pregnancy terminations are important sources of stem cells. Scientists extract stem cells from gonadal tissue, liver tissue, neural tissue and mesenchymal tissue (Kent, 2008). Oöcytes, while not themselves sources of stem cells, are nevertheless essential components in Somatic Cell Nuclear Transfer (SCNT) research, aimed at producing genetically matched transplantable tissues for clinical use.[4]

Each of these forms of stem cell tissue is valuable because it partakes of the generative nexus of the maternal-foetal body, the ability to continuously produce organized tissue that develops along particular biological pathways. The stem cell sciences aim to transform this generative capacity into regenerative capacity—to divert this productivity away from the generation of new individuals and toward the regeneration of existing populations. The stem cell industries have developed a repertoire of technical innovations which mobilize the generative potential of such material. These include cryopreservation (freezing) which retains the material in a stable state with its generative powers intact, and stem cell lines, which are made by disaggregating embryos into single cells and configuring them so that the cells reproduce themselves in the laboratory, galvanizing the developmental powers of embryonic material without producing actual embryos. The material can then, in theory at least, be transplanted into a human body and its generative powers become regenerative, repairing damaged sites and restoring function.[5]

However, securing this generative potential involves negotiating with potential female donors in various ways. In the case of embryo donation for stem cell research, national and provincial states have taken the lead by providing regulatory frameworks and encouraging bioethical oversight. From the early 2000s onward a number of the OECD countries have developed regulatory systems which permit IVF clinics to solicit so called ‘spare’ embryos—embryos produced as part of *in vitro* reproductive procedures, but designated surplus to reproductive requirements (Gottweis, Salter and Waldby, 2009). For women undergoing IVF and for clinical staff working with them, designating an embryo as ‘spare’ is not particularly straightforward (Ehrich et al., 2007). Nevertheless, it is a locution which renders non-implanted embryos as both a form of waste and a valuable surplus that should be given so its value to others can be actualized. This formulation has largely been successful in securing donations of embryos to stem cell research from women who are often knowledgeable about stem cell research and who feel a moral obligation to contribute (Parry, 2006).

Currently many legislatures are also attempting to frame similar regulatory systems for oöcytes, but these have proved a much more recalcitrant negotiating point with potential donors. The production of multiple oöcytes is the most onerous part of any fertility procedure, involving extended hormone treatment and surgery, and the endurance of risk and discomfort (Steinbrook, 2006). They are not easily designated as a form of surplus, because women in IVF may have relatively infertile oöcytes, and often want to deploy all of them for reproductive bids. There is no satisfactory way to preserve oöcytes—they cannot be safely frozen—and so if donated for SCNT work they must be fresh. Hence they are more rare and singular, and women have proved unforthcoming even for reproductive donation, so that IVF clinics routinely have long waiting lists for oöcytes. In the UK this recalcitrance is being negotiated through so called 'egg-sharing' arrangements, which sounds like a gift relation but is in fact a transactional one, where women agree to donate oöcytes for research in exchange for reduced IVF fees (Roberts and Throsby, 2008). In the United States, oöcytes are highly transactional objects, circulating on an unregulated market, and debate rages within the stem cell research community whether to accept and utilize this market to obtain research oöcytes, or to introduce regulations which would bring US research into bioethical line with the regulations of collaborator nations. Beyond these two leading bioeconomies, many developing and even developed nations do not regulate oöcyte transactions, and a global market has developed in which transnational fertility companies purchase oöcytes from relatively impoverished vendor populations and sell them to more wealthy fertility tourists (Waldby, 2008).

Foetal material, perhaps the least publicly known source of stem cells, has been harvested from pregnancy terminations for medical research since abortion was decriminalized. In the UK, for example, women planning a termination in certain clinics with links to research programmes are approached by a research nurse to consent to the foetal tissue being harvested for research. Under the Polkinghorne guidelines which govern the field, they receive little information about the kinds of medical research that this might involve. The terminated foetus itself is classified as a cadaver, and, as Kent (2008) notes, the use of foetal tissue for stem cell research is constituted as making valuable use of what would otherwise be shameful waste. The donation process itself is relatively unceremonious, in contrast to the elaborate information and consent protocols that govern embryo donation for stem cell research, and the donors often remain uneasy about the unspecified final uses made of their foetal material (Pfeffer, 2008).

Finally, cord blood can be procured for the haematopoietic stem cell industry through private cord blood banking, a commercial contractual innovation, rather than a regulatory structure created by the state. Cord blood companies like Pluristem and Cordlife solicit pregnant women through various types of advertising to open a private cord blood account for their child. The blood is collected during birth, and the account is retained for an annual fee, available in case the child or another compatible family member requires treatment for a blood disorder, or for conditions that may become treatable with stem cell therapies in the future. Private cord blood banking hence relies heavily on the speculative and promissory claims made about currently non-existent stem cell therapies, and creates its markets in part by inviting clients to invest in the future of their child by investing in the future of regenerative medicine. Private cord blood banking is not a gift system, but structured more like a form of investment in a commercial bank, whose investors supply cord blood companies with both capital *and* biological material for research (Brown and Kraft, 2006; Waldby, 2006). Such private, autologous tissue banking services are set to expand as stem cell research identifies more and more sites of stem cell concentration (e.g. baby teeth) that may provide sources of self-regeneration in the future.

So we can see that particular groups of women are being integrated into the lower echelons of the stem cell industries as essential productive agents through various contractual mechanisms, institutional arrangements and regulatory systems. Generally speaking, the stem cell industries have found ways to procure reproductive biological material from women in the developed nations without entering into direct forms of transaction. Embryos, oöcytes, foetal material and cord blood have been configured, both through regulations and rhetorics, as a wasted form of vitality if they are not given to stem cell research. By giving to stem cell research, donors give either to a future imagined community, rendered healthy by these new regenerative therapies, or to the future of their own children, secured through private autologous tissue banking.[6] Amongst all of these new forms of negotiation, securing access to oöcytes has been the most difficult, and the most advanced bioeconomies, the UK and the USA, have resorted to more or less frank forms of transaction (egg-sharing and market exchange respectively) to secure supplies. Such frank transaction also characterizes oöcyte procurement in Eastern and Southern Europe, and parts of South and East Asia, and there is evidence to suggest that some women use oöcyte vending as a repeated and essential source of income (Nahman, 2005; Barnett and Smith, 2006).

LABOUR AND THE STEM CELL INDUSTRIES

We want to argue that women who donate or transact their biological material to the regenerative medicine industries are engaged in a form of labour, even though the terminology of labour is not used in these contexts. Tissue providers to biomedical research are generally cast as altruistic donors whose tissues are adjudicated through bioethical rather than economic frameworks, even in cases where they are paid a fee and the recipient is a commercial entity (Tober, 2001). Life sciences research now constitutes an important sector of several national economies (OECD, 2006) and bioeconomic development cannot proceed without access to the biological capacities of living human bodies, which form essential components of the experimental systems put in train by biomedical research. Nevertheless, when the bioeconomy is analysed in terms of labour, attention invariably turns to the value created by highly skilled, scientific labour, understood to perform the work of creative innovation necessary to transform biological life into industrial, therapeutic or agricultural processes (Ashish and Gambardella, 1994; Gambardella, 1995). The organization of intellectual property in the life sciences recognizes the cognitive labour of the scientist and the clinician, but not the constitutive nature of the biological material or the collaboration of the donor (Pottage, 1998). It is evident then that the recognition of labour here is structured by a mind/body split, wherein the embodied productivity of the tissue donor does not figure.

In our analysis, however, this embodied productivity is given a central place. Stem cell researchers require access to women's *in vivo* reproductive biology, the living interior processes of their bodies, as a generative site for biological materials. The donor's participation in this process is generally conceptualized as deliberative and contractual; that is, they participate insofar as they make an informed decision to consent to donation. However, we would contend that their participation should be understood as a thoroughgoing embodied collaboration that involves not merely the legal disposal of surplus biological material but rather the generative energies of the donor's biology, sustained over time. While the legal act of donation takes place *after* IVF, super ovulation, termination or birth, the *genesis* of the materials takes place through a drawn out and complex interaction between the woman's subjectivity; the trajectory of her reproductive biology; the social and biomedical technologies which order that trajectory; the regulatory environment which allows maternal populations to be solicited, informed and mobilized as donors; and the technical repertoire of stem cell research which redirects the developmental pathways of maternal fertility, embryogenesis, foetal development and the birth process. In the process of this collaboration, the donor is caught up with various forms of effort, compliance, self-care and drug administration, *in vivo* risk and transformation (Throsby, 2002; Nahman, 2005) and this corporeal vulnerability and flexibility is technically and socially configured to the requirements of stem cell research. The labour involved in this collaboration goes unrecognized in part because it takes place at the level of women's biological embodiment, and hence it is readily naturalized, in much the same way that women's emotional labour in the service industries is taken for granted as a given feminine attribute (Weeks, 2007). Moreover, it is a form of labour not amenable to quantification in linear, abstract units of time and codified tasks; rather it takes place through the complex time of reproductive metabolism, endocrine circulation, and the unfolding of ontogenic processes, recalibrated through assisted reproductive technologies and stem cell technologies. Hence it is a labour process that remains somewhat opaque to conventional industrial methods for the calculation of productivity.

THE REPRODUCTIVE LABOUR DEBATES

In many respects, our proposal to cast these interactions as a form of labour is not new, and several other feminist commentators have made similar moves with regard to the stem cell industries. These commentators have sought to draw parallels between industrial production and reproduction, and they explicitly build on the materialist feminist analyses of reproductive labour developed in the 1970s and early 1980s. So Charis Thompson, in her ethnographic work on North American fertility clinics, develops the idea of a 'biomedical mode of reproduction' (Thompson, 2005) akin to the industrial mode of production. In the biomedical mode of reproduction, 'reproduction [is made] productive in an industrial sense, with its product being standardized molecular entities like clones and cell lines' (Thompson, 2005: 253). The patients who produce these tissues are likened to workers who are alienated from their labour. Margaret Lock and Sarah Franklin draw on Thompson's formulation[7] in their analysis of the contemporary life sciences, placing the processes of reproduction at the centre of capitalized biosciences as the 'primary generator of wealth, agency and value' (Lock and Franklin, 2003: 7). They note that 'Thompson's proposal for reconceptualizing the way biocapital is generated draws on a long history of feminist critiques of Marxist approaches, which overemphasize production at the expense of reproduction' (p. 9) and argue that 'reproduction—like gender, nature and kinship, often feminized—has been wrongly marginalized in accounts of economic change and development' (pp. 10–11).

Donna Dickenson has gone furthest in reworking the materialist feminist concept of 'reproductive labour'. Like Thompson, she draws on the idea of alienated labour, to characterize the feminine contribution to the stem cell industries. She argues that the neglect of women's contribution rests on a historical lack of recognition for the work of maternity more generally, an indication of women's absence of property rights in their own reproductive labour. She notes the history of feminist analyses that have 'extended the logic of alienation into the home'. She continues,

> If reproductive labour in the home can be viewed as alienated, then certainly alienation can be applied to reproductive labour

> outside the home, and to a situation where there need be no inverted commas around 'product'. Although children are neither property nor truly a product, stem cells are both. When women labour to produce the intermediate product used in the stem cell technologies, ova available for enucleation, there can be no question that their labour is neither natural nor performed in a realm extraneous to capitalism. Their reproductive labour has entered into the very heart of one of the most thriving applications of modern biotechnology, and they are liable to oppression in that site. (Dickenson, 2007: 76)

In each of these cases these commentators have introduced the idea of industrial production and feminized labour to counter the relegation of feminized donation to the domain of altruism and gift relations, a domain, like the family, understood to be beyond the transactional relations of commerce (Titmuss, 1997). Like the materialist feminists of the 1970s and 1980s whom they invoke, they want to relocate this feminized productivity within the circuits of economic value, as do we. However, while this work is enormously suggestive, our concern is that it seems to reproduce inadvertently a Fordist industrial model of labour and the nation-state model of reproduction, both of which have been significantly displaced in the emerging economies of clinical labour associated with regenerative medicine.

If we re-examine the premises that informed the reproductive labour debates of the 1970s and 1980s we can see that they are firmly located in the particularities of Fordist/Keynesian social and economic relations. Materialist feminists such as Christine Delphy (1984), Michelle Barrett (1980) and Nancy Hartsock (1998) followed Henry Ford himself in arguing that the Fordist/Keynesian model of society could only sustain itself if a certain class of women (the middle class) were compelled to return to the domestic space of reproduction.[8] Here women were expected to perform a multitude of tasks—childbearing, childcare, housework—that were not paid but were in fact essential to the whole regime of Fordist labour relations and the organization of the welfare state. By reconfiguring these tasks, normally understood as part of a 'natural' feminine/maternal gift economy as 'unpaid domestic labour', the materialist feminist tradition points to the foundational economic role of reproduction within the Fordist/Keynesian social contract.

The appeal of this approach for contemporary feminist analysts of the bioeconomy (OECD, 2006) is its strong historical and conceptual parallels with the post-war development of the gift economy for human tissues, which also played a foundational role in the organization of the welfare state. After the war, national blood banks were established in Western Europe and some Commonwealth countries as part of the new national health services, and citizens were enjoined to give blood, and later other tissues, for their fellow citizens and the public good, as part of the redistributive ethics of the national welfare state. The most eloquent expression of this relationship between the welfare state and distribution of human tissues can be found in Richard Titmuss's celebrated polemic *The Gift Relationship: From Human Blood to Social Policy,* published in the late 1960s. Titmuss argues that blood must be given rather than sold because the egalitarian circulation of gifts is the essential form of value which underpins the welfare state and the relation among citizens (Titmuss, 1997).

Each of these spheres of gift exchange, domestic reproduction and tissue donation, was the product of the welfare state's decommodifying action (Cerny, 1997), the regulatory exclusion of particular spheres and social relations from markets as a way to promote social stability (through a gendered hierarchy in the case of reproductive labour). When Titmuss argues that blood must be rendered as a gift and not as a commercial transaction, he is formulating an argument that is very close to Ford's in relation to domestic work. Far from indicating its peripheral status, the 'extra-economic' character of blood donation is precisely what establishes its foundational role in the Keynesian welfare state.

As we have noted at several points, the gift system for soliciting human tissues for clinical therapies and biomedical research is still operative, despite the wholesale commercialization of the human tissue economy *after* donation (Waldby and Mitchell, 2006). Hence the strategy used by materialist feminist commentators, to reposition women's gifts as a form of unrecognized and alienated reproductive labour, still seems plausible as a way to construe the agency and value of maternal donor populations. However, our concern is that a conceptualization of labour adequate to current conditions needs to take into account the salient transformations in both labour and reproduction which have occurred over the last three or four decades, as well as the regulatory, commercial and technical transformations in biomedical research.[9] In the following sections we will outline the features of these transformations.

POST-FORDISM AND REPRODUCTION

With the decline of the family wage and the dramatic increase of women in the paid work force from the 1970s onward, the shift towards post-Fordism undermines the very separation of spheres that was constitutive of the Fordist middle class, renegotiating the boundaries between reproductive and productive labour, gift exchange and transactional service. Hence the critical force of the term 'reproductive labour' is somewhat mitigated, since in many cases what was once unpaid housework performed by middle-class women is now unquestionably *labour,* a service that is often contracted out and sold on the market. The neo-liberalization of former welfare state domains like health care has actually increased the demand for care labour, but middle- and upper-class professional women increasingly employ other women as nannies, private nurses and cleaners to carry out such care (Bakker, 2003). The entire lower end of the 'service' sector is disproportionately dependent on the labour of local racial minorities and migrants, most of whom are female (Sassen, 2003). Hence we argue a major difference between Fordist uncompensated reproductive labour and the contemporary relations of reproduction is *a denationalization of the reproductive sphere and its exposure to global precarious labour markets.* The fact that these labourers often have an uncertain relationship to citizenship rights is not incidental—their susceptibility to state detention, forced return and other punitive security interventions is precisely what maintains their wages and conditions at such low levels.

At the same time, the gift economy for human tissues, while still operative, is increasingly fragmented, as the commercial drive for bioeconomic innovation places more and more demand pressures on tissue procurement. In fact, gift economies have never been sufficient to meet the clinical and research demand for tissues, and have always required supplementation from less voluntary and more transactional forms of procurement. Even at the height of the gift relation advocated by Titmuss, in the 1960s and 1970s, blood banks resorted to purchasing blood plasma from global pharmaceutical companies, who in turn purchased blood from impoverished, third world populations (Starr, 1998). Today, as bioeconomic innovation becomes a more important sector of the global economy, both gift and market systems of recruitment are placed under increasing pressure and, we would argue, are losing their distinctiveness. *De jure,* tissue donation is still gratuitous in most Western European and Commonwealth countries, but *de facto,* the commercial and bioeconomic policy pressures on donation have seen the multiplication of various forms of remuneration and transaction. States in most of the developed nations have managed to preserve particular sectors of tissue donation *hors commerce* (for example solid organ donation), but the borders between gifting and transactional exchange are increasingly unstable. So, for example, women in British IVF programmes may find themselves both receiving heavily discounted reproductive treatment in exchange for a proportion of their oöcytes, while being asked to gratuitously donate their 'spare' embryos for stem cell research through a carefully worded informed consent procedure which emphasizes the virtues of the gift relation and the donor's lack of property rights in their donated material. Here the claims of the gift relation are destabilized by the fact that donors to stem cell research give not to a fellow citizen (the ethical model described by Titmuss) but to an increasingly capitalized life sciences sector, which depends more and more transparently on the generally unremunerated labour of the donor.[10]

At the same time, the national citizenship model of blood and tissue donation is being undercut by emerging transnational circuits of tissue exchange. These circuits are often closely aligned with the geographies of labour migration that characterize more familiar forms of informal feminized service labour such as prostitution, cleaning and childcare. In parts of Eastern and Southern Europe for example, as we noted briefly above, private transnational IVF clinics broker sales between mobile oöcyte vendors and infertile couples from heavily regulated systems, such as those in Britain who are in search of reproductive tissues. As research using embryonic stem cell lines steps up, the shortage of oöcytes, already a problem for IVF treatment, has become even more urgent, and at least one documented case has emerged of a transnational oöcyte brokerage firm supplying material for stem cell research as well as treatment (Paik, 2006). In this context, the sale of eggs has become a viable source of income for some women living on the economic margins of Eastern Europe or other transitional economies, many of whom are otherwise engaged in the standard forms of female service labour such as domestic work and prostitution. Meanwhile, in the United States, where oöcytes can be sold on an unregulated market, the demand for research oöcytes opens up vending opportunities to African-American and Latina women who are normally excluded from the reproductive oöcyte market, which favours fair skinned women with higher education attainments (Pollock, 2003).

However, in order to fully appreciate the qualitative difference between the reproductive labour of women as maternal producers and providers in Fordist society and the bioeconomic labour performed by women today, it is necessary to move beyond the transformations in broad political economy. We will now turn to consider in more detail the form of value produced by clinical labour, and the kind of action it implies. While the other feminist accounts of biomedical reproductive labour discussed earlier revolve around a dynamic of alienation, we will suggest that clinical labour is about the transaction of biological potential and the creation of experimental relations. We contend that the renegotiation of bodily limits and productive possibilities has become *the core business of bioeconomic innovation.*

RETHINKING LABOUR: POTENTIAL, EXPERIMENT, REGENERATION

Recent analysts of the 'new economy' argue that its modes of value and accumulation are oriented towards the organization of potential: the prospecting for new sites of possibility, vitality and future commercial energies (Adkins, 2008). Thrift (2006) argues for a similar orientation. For him, post-Fordist knowledge economies are oriented to the relentless search for new techniques, value-added commodities, modes of communication and ways to orient and treat the body, as essentially *experimental* economies. As he puts it, the post-Fordist mode of accumulation attempts to 'squeeze every last drop of value of the system by increasing the rate of innovation and invention through the acceleration of connective mutation. . . . instead of being thought of as a passive store, knowledge is thought of as a set of continuously operating machines for activating competences, risk taking and readiness to innovate' (Thrift, 2006: 281). Connective mutation here refers to the emergence of unpredictable and potentially valuable relationships between expertise, technical capacity, commodity forms and consumer demand.[11] The experimental economy is concerned with both the provocation of unpredictable synergies and the capturing of value potentials that emerge from such synergies. The sociological literature focused on biomedical innovation is similarly concerned with the importance of promissory value, its constant appeal to future therapeutic applications and its growing reliance on intellectual property rights, which secure licensing rights over the possible future uses of an invention (Brown and Michael, 2003; Waldby, 2006; Cooper, 2008). This promissory orientation derives in part from the uncertainty of the life sciences research and development pipeline and reflects the centrality of financial forecasting and market projection in stock market valuation of firms. However, it also derives from the vitality and open-ended performativity of the biological itself, provoked by new ways of bringing technical and experimental systems into relation with living bodies. This last point is crucial for understanding what is at stake in an analysis of women's labour in the stem cell industries.

The accounts of reproductive labour presented previously rely on a Marxist theory of alienation applied to the industrial mode of production. Where the early Marx envisaged industrial labour as a form of estrangement in which the subjectivity of the implicitly male worker is separated from the instrumental capacities of the organic body (Marx, 1974), the feminist critics discussed earlier (Lock and Franklin, 2003; Thompson, 2005; Dickenson, 2007) argue that women are alienated from the products of their reproductive labour—in this case, the oöcytes and embryos that are used in both IVF and regenerative medicine. Marx's theory of alienation depends on a particular vision of the body as an organic whole, which is then separated from itself through the act of exploitation; the materialist feminist perspective extends this hypothesis to the female body, whose reproductive integrity is assumed to suffer a similar estrangement when providing tissues for biomedicine. Intrinsic to the concept of alienated labour is also a particular understanding of temporality. Marx conceives of the relationship between labour and the commodity form as a retroactive one, in which the living labour force expended in the present is congealed as *past* or *dead* labour in the exchangeable commodity. Again, the feminist materialist perspective seeks to extend this insight to women's reproductive labour, arguing that the 'products' deployed in the contemporary biosciences are merely the past or frozen products of women's living reproductive potential. The intellectual lineage of the concept of alienated labour certainly justifies such an analogy, since Marx's early writing on alienated labour depends on a conception of the organic, reproductive body that is derived directly from Hegel's

Philosophy of Nature ([1830] 1970).[12] Yet we would suggest that the very understanding of organic, reproductive life which is relayed by such a tradition has been significantly displaced by the contemporary political economy of the life sciences and calls for a corresponding reworking of the categories of both 'labour' and 'life'. Hence, we suggest the term 'regenerative labour' rather than 'reproductive labour' as a more precise designation of the form of productivity at stake.

We can explicate our claim by comparing the biology of assisted reproduction with the biology of stem cell technologies, and the different forms of productivity they engage. For the greater part of the 20th century, assisted reproduction technologies and IVF have been devoted precisely to the mass reproduction of animal life for industrialized agriculture (Clarke, 1998). The *technology* of human IVF emerged from the livestock industry although in institutional and economic terms it was never organized along the same lines of mass reproduction that reigned in the livestock industry. Human reproductive IVF does not involve reordering the developmental biology of cells, but rather facilitating fertilization; creating embryos *in vitro* only as a preliminary to their transfer into the woman's uterus and the unfolding of the developmental pathways which may eventually produce a child. The process is organized precisely to *preserve* the ontogenic and teleological potentials of the germinal cells, their trajectory towards the reproduction of the organism in interaction with the maternal body.

Stem cell technologies, however, are concerned with the disruption of this teleology and experimentation with cellular potential. They rely on IVF technologies to disentangle reproductive material from the maternal body, yet as the oöcyte or embryo passes from the IVF clinic to the stem cell laboratory, it also passes from one institutional, legal and scientific context to a dramatically different one. Formally 'reproductive tissue' enters into another epistemological space where the potentiality of the germ cell is defined in radically different ways. One of the prime innovations of stem cell science is to have reworked formerly orthodox understandings of cell potentiality. This is true of both somatic (nonreproductive) and germinal (reproductive) cells such as the egg or sperm. In each case, a notion of potentiality that formerly limited their future possibilities of division and differentiation to the evolving organism now detects a radically different, even incommensurable spectrum of possibilities in the same tissue specimen. In the SCNT process, an oöcyte is used to reactivate the pluripotency of dedicated somatic cells. That is, a somatic cell (a skin cell for example) can be taken back along its developmental pathway so that it regains its former embryonic ability to unfold into all tissue types. SCNT was the process used to clone Dolly the sheep in 1996, and subsequently many other animals, although the technology has not yet been successfully used to create human embryos. Prior to Dolly, it was assumed that the nuclei of adult cells had lost their pluripotency, that is, once programmed to produce a particular kind of cell, they lost their ability to produce different kinds of cells (Keller, 2000).

Stem cells derived from IVF embryos are disaggregated from the blastocyst, the elementary level of organization (mesoderm, and so on) that begins the production of the organism. Their pluripotency is instead *diverted* into the production of a cell line, a technique which both immortalizes the tissue and facilitates its self-perpetuating potential *in vitro*. The embryonic stem cell line can produce any of the specialized, fully differentiated cells that constitute a developing organism, while continuing to divide and produce more stem cells in an uncommitted, ex-organism state. In each case, it is the cell's potential which is at stake; their future possibilities of differentiation are always *in surplus* of the finite possibilities of differentiation available to the developed organism. Hence, their scientific value resides in their promised capacity to provide 'inexhaustible' reserves of flexible, transplantable tissue, the promise (and the fantasy) of an endlessly self-regenerating, frictionless biology.

It is therefore not only the infrastructure of contemporary biomedicine that is being reorganized around an economy of promise, potentiality and expectation, but also the temporality of the cell. In the words of cell biologists Loeffler and Potten, 'the main attributes of stem cells relate to their potential in the future' (Loeffler and Potten, 1997: 13); 'all statements that we can make [about stem cells] will be necessarily probabilistic statements about the future behaviour of the cell under consideration' (p. 14); thus 'stemness is not a property but a spectrum of capabilities from which to choose' (p. 1). According to this reworking of bodily potentiality, the cell is no longer determined by its specific lineage or committed to a path of progressive differentiation and loss of potency but can also enter into a cycle of embryonic self-accumulation by which bodily potentiality can be regenerated indefinitely, independently of the chronological trajectory of the organism. As a form of biotechnical regeneration, this is far removed from the model of reproductive, organic life that Marx inherits from Hegel's *Philosophy of Nature*. Through the mechanism of informed consent, women who donate their tissues to the stem cell industries are effectively contractually engaging their bodies with these experimental systems and promissory economies, giving not so much the products of reproduction as technical and legal traction on their bodily potentials for regeneration. Here the act of consent can be understood along the lines of Pateman's *Sexual Contract,* not as the exercise of rational, deliberative judgement but as a transaction of the capacities of the female body (Pateman, 1988). The technologies of stem cell research directly engage with these capacities, and have extended them well beyond their historical use values for sexuality, reproduction and nurture, into an experimental realm of potential and regenerative action whose social and biological limits are presently unknowable. Like all promissory economies, however, both stem cell science and the biotechnology industries speculate on the future of innovation, and it remains to be seen if the promise of regenerative biology can be scientifically or socially realized. Successful realization will depend in part on the kind of contractual exchange the stem cell industries can negotiate with the particular groups of women we have identified.

CONCLUSION

We write at a time when more and more ways are being found to capitalize on women's reproductive biology. Alongside the global market for reproductive oöcytes, we see the rapid expansion of transnational surrogacy markets, as couples from the developed economies turn to women in India to gestate their children, at rates which undercut the long-standing US surrogacy industry (Prasad and Ghosh, 2008). While this activity can be characterized as reproductive labour, the contractual production of maternal fertility for a purchaser, we have argued here that the involvement of women in the stem cell industries requires a distinct form of analysis. Rather than simply adding an additional reproductive capacity to a female body already committed to reproductive labour, the stem cell industries require us to acknowledge the mutual constitution of politico-economic and technological conceptions of potential itself. If different modes of technical production, scientific speculation and economic calculus call forth different capacities from the body, it is the very conception of what the body is capable of doing—the work it is capable of rendering and the experimental systems in which it can play a part—that is under negotiation in the encounter between reproductive and regenerative medicine. While reproductive medicine demands a literal labour of reproduction from the female body, regenerative medicine is interested in the body's capacity for embryonic self-regeneration, prior to and independently of any process of development. Bodily potentiality is itself being reconfigured at the interface of new labour relations and the biological sciences.

NOTES

1. In her study, the exemplars of emotional labour were flight attendants.
2. The exception here is the unregulated US market in oöcytes.
3. Anecdotal evidence suggests that many women engaged in reproductive services in, for example, India are not from the lowest social echelons but rather from the lower middle class, a population presumably preferred by clinics because of their better health. Nevertheless, such groups are relatively impoverished compared to the middle-class Europeans and North Americans who purchase their services.
4. SCNT, sometimes called therapeutic cloning, involves the creating of an embryo not by the usual process of *in vivo* conception, fusion of egg and sperm, but through the *in vitro* insertion of the nucleus of a cell from an adult's tissues into an oöcyte, an unfertilized egg. The oöcyte has in turn been enucleated—had its own nucleus removed to make way for the introduced nucleus. This creates an embryo with the genome of the adult from whom the nucleus was taken. Such an embryo could theoretically be transformed into an embryonic stem cell line which could act as a source of perfectly histocompatible, transplantable tissues for the person who donated the nucleus. This technique, which has not yet been successfully performed with human tissues, is the highest aspiration of stem cell research, because it would solve the biological problem of tissue matching and (in theory at least) the logistical problem of organ shortages, as well as facilitate treatments for currently untreatable degenerative conditions. It remains to be seen if such a technique could be standardized and made sufficiently affordable for public medical treatment however.
5. Most regenerative medicine is somewhat theoretical, in that many proposed treatments using embryonic stem cells (ESCs) and cord blood are not yet clinically tested. Geron, a large US based stem cell company, at time of writing has just launched the world's first phase one clinical trial using ESCs for the treatment of spinal cord injury. Many of the claimed possible uses for cord blood depend on solving a range of technical problems related to differentiation and scaling up of material.
6. The appeal to a future imagined community is evident, for example, in a recent public appeal for altruistic donation of oöcytes to stem cell research. Ian Wilmut, creator of Dolly the sheep, recently called for young British women to donate oöcytes to assist with stem cell research into motor neurone disease. In an interview with *The Guardian,* Professor Wilmut said, 'I have never doubted that women would donate if they thought we were helping people to have treatment. Our hope and belief is that women who have seen the devastating effect of this disease will be prepared to make such a donation' (Sample and Macleod, 2005).
7. Here the authors draw upon an earlier version of her argument.
8. For Henry Ford's own reflections on the family wage, see May (1982). For an extensive discussion of the value and shortcomings of the materialist feminist tradition from a contemporary perspective, see Weeks (2007).
9. This is not to say that there are no exceptions. See for example Truong (1990) and Bakker (2003) for a consideration of post-Fordist transformations in gender, race and labour which draws on the materialist feminist tradition.
10. Tissue donation under these conditions resembles the 'free labour' identified by Tiziana Terranova (2004) who uses the term to describe the voluntary work performed by IT enthusiasts in creating public content, programming code etc. in the digital economy. Terranova notes that 'the conditions that make free labour an important element of the digital economy are based in a difficult, experimental compromise between the historically rooted cultural and affective

desire for creative production and the current capitalist emphasis on knowledge as the main source of value-added' (p. 36).

11. The term 'connective mutation' was originally coined by Franco Berardi (2005).
12. In his early theory of labour alienation, which appears in the *Economic and Philosophic Manuscripts of 1844* (1974), Marx refers not only to the familiar dialectic of labour outlined in Hegel's *Phenomenology of Spirit* but also and more directly to the *Philosophy of Nature* (1830), where Hegel is interested in the dialectic of genus and species, or generic and organic life. Significantly, for Hegel the internal negativity or 'auto-alienation' of the human as species takes the form of sexual difference. The influence of Hegel's text is evident in Marx's analysis of species life, where he conceives of labour as the self-alienation of the productive organism, but more specifically as the self-alienation of the reproductive male organism—in other words, as castration. The difficulty here is that the sexual dimension of Marx's theory of labour alienation is both loudly asserted at the textual level and obscured in terms of its political and theoretical consequences. In this respect, it could be argued that feminist theories of alienated reproductive labour merely draw out the full consequences of Marx's theory of the labouring organism. Our point is that in doing so, they also remain within the genealogical dialectic of Hegelian and Marxist philosophy, where the auto-alienation of the organic male body is conceived of as castration and that of the female body as the separation between mother and child.

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CHAPTER 26

Beyond Postcolonial Theory: Two Undertheorized Perspectives on Science and Technology

Sandra Harding

Orientalism depends for its strategy on this flexible positional superiority, which puts the Westerner in a whole series of possible relationships with the Orient without ever losing him the relative upper hand. And why should it have been otherwise, especially during the period of extraordinary European ascendancy from the late Renaissance to the present? . . . There emerged a complex Orient suitable for study in the Academy, for display in the museum, for reconstruction in the colonial office, for theoretical illustration in anthropological, biological, linguistic, racial, and historical theses about mankind and the universe, for instances of economic and sociological theories of development, revolution, cultural personality, national or religious character.

—Edward Said, *Orientalism*

Resistance to the critique of Eurocentrism is always extreme, for we are here entering the realm of the taboo. The calling into question of the Eurocentric dimension of the dominant ideology is more difficult to accept even than a critical challenge to its economic dimension. For the critique of Eurocentrism directly calls into question the position of the comfortable classes of this world.

—Samir Amin, *Eurocentrism*

Historically it was activists and intellectuals in or from the colonies and newly decolonized nations that most effectively articulated the opposition to colonialism, imperialism, and eurocentrism; these critiques were allied to those developed in the west. What is so striking in retrospect is the sheer energy, volume, and heroic commitment of the intellectual as well as political opposition to colonialism, and that productively continued into the postcolonial period. Postcolonial studies has developed that work to give it a disciplinary focus, and foregrounds its significance. For the first time, in a move that was the very reverse to that which Said describes in Orientalism (1978), the power of western academic institutions has been deployed against the west. For the first time, in the western academy, postcolonial subjects become subjects rather than the objects of knowledge. For the first time, tricontinental knowledge, cultural and political practices have asserted and achieved more or less equal institutional status with any other.

—Robert J. Young, *Postcolonialism*

According to Western policymakers after World War II, the world peace that so many desired required greater investment in scientific and technical research.[1] World peace could not occur without democratic social relations, and this in turn required economic prosperity for all societies. Poverty drove desperate peoples to support irrational beliefs of the sort that had led to World War II. It was only Western scientific rationality and technical expertise that could boost economic prosperity for poor societies, thereby attracting people to rational forms of political participation. Consequently, it was the duty of Western societies to increase their scientific and technical research and to disseminate the results to poor societies. The newly established United Nations, joined by many Western countries, moved quickly to set up agencies to deliver economic development to poor societies around the globe. The green revolution in agriculture was just one of the results of such research projects.

This way of looking at science and social progress is grounded in modernization theory, which is itself rooted in the Enlightenment belief in the beneficial powers of scientific rationality. The West's sciences and technologies were supposed to be the jewels in the crown of modernity. To achieve social progress, value-neutral scientific rationality and technical expertise must replace traditional religious beliefs, myths, and superstitions about nature and social relations. To be sure, valuable aspects of this legacy endure. Some have said that we need much more rationality and modernity to engage in realistic and democratic ways with global challenges today (Harding 2008).

Yet the way this view is articulated in the preceding two paragraphs obscures perhaps as much as it reveals about science and society in history. Indeed, at the very moment that leaders of U.S. scientific institutions were proclaiming the autonomy of science from society as a reason to support increased funding for scientific and technical research, both the United States and its allies as well as the Soviet Union were vigorously directing research toward projects intended to win superiority in the Cold War arms race. Would this arms race bring world peace? Many believed it would. At any rate, at the time it seemed preferable to another "hot war," this time with nuclear weapons.

Moreover, the U.S. Congress noticed that it had been permitted no oversight over the huge expenditure of taxpayer funds in the Manhattan Project, which had created the atomic bomb. Nor would Congress get to have such oversight in how the newly established National Science Foundation would be distributing federal funds. As one historian notes, the "autonomy of science" rhetoric from leaders of the scientific community was specifically intended to forestall government "meddling" in the agendas and practices of the scientific community. Science was already a "little democracy," proclaimed spokesmen for the scientific community, so it needed no government oversight of the sort taxpayers usually expected (Hollinger 1996). Most of the time, this is widely regarded as a sensible precaution to protect research from the shifting winds of political whim, However, skeptics could well wonder if all this research directly sponsored and directed by government interests, in addition to corporate interests, should still be regarded as economically, politically, socially, and culturally value neutral.

Soon the "unaligned nations," as they were named by the Cold War participants, transformed themselves into the Third World. Many Third World intellectuals began strategizing about what should be the science and technology policies of their own newly independent countries, since these countries were no longer under formal Western rule. As part of this project, they analyzed the contributions that Western sciences had provided to colonialism and that colonialism, in turn, had provided to Western sciences. These new histories began to appear as early as 1959. In that year an influential essay by Frantz Fanon was published, which demonstrated that under colonialism, just as under Nazi rule, doctors were complicit with "state-sanctioned barbarism" (Fanon 2002). Philip Curtin's analysis of how Western medical achievements made it possible for Europeans to colonize the interior of Africa appeared two years later. One of his examples was the development of quinine for use against malaria (Curtin 1961). More counterhistories to the standard Western accounts of the history of science followed, alongside analyses by anthropologists and biologists of the strengths of traditional health, agriculture, and environmental practices. These produced additional reasons to question central assumptions of modernization theory and its Enlightenment-grounded philosophy of science.[2]

Now, five decades later, a good-sized literature has further developed a postcolonial framework for thinking about sciences and technologies.[3] It has produced startling insights about how sciences function in the everyday push and pull of local and global political, economic, social, and cultural relations. These intellectuals have argued from the beginning that modern Western sciences have been "epistemologically under-developed"; they lacked the resources necessary to recognize their own locations in social relations and history.[4]

It remains puzzling that the issues raised in this literature are only now beginning to attract the attention of broader audiences in the West. One can find relatively little engagement with these postcolonial science and technology writings in university curricula or in relevant research fields such as the sciences themselves or the philosophy and social studies of science. (Histories of non-Western sciences and the anthropology of medicine provide important exceptions here.) The postcolonial writings mostly seem to be over the horizon and out of view of other kinds of lively discussions of science and technology issues in our universities and research fields. However, in the last few years, promising signs of more robust encounters with issues raised in the postcolonial writings have begun to appear. A few journals in the field of science and technology studies have published special issues devoted to such topics.[5] The third edition of a prominent science and technology studies handbook included a provocative review article (Anderson and Adams 2007). A leading journal in postcolonial studies published its first issue devoted to the topic (Seth 2009a). Yet in 2009 one of the authors of that review article could still say that "most STS scholars have not seen the point of postcolonial theory. . . . and most postcolonial theorists . . . have flocked instead to the analysis of literary texts" (Anderson 2009, 390).

We could probably identify many causes of this history of disinterest in the West in postcolonial issues about science and technology. This is so even though these issues are about us in the West and our sciences and technologies and not just about distant others who are "out there" in the Third World. Western self-interest, Eurocentrism, racism, and a fascination with globalization theory have been mentioned as possible causes. Perhaps another cause worth considering is the preoccupation with Cold War agendas. From the end of World War II until the fall of the Soviet Union in 1989, such preoccupations made it difficult for Westerners to become interested in thinking about the tension between, on the one hand, assumptions that the value neutrality of modern sciences was both desirable and possible and, on the other hand, the clearly political and economic missions to which so much scientific research was dedicated.[6] Sympathetic attention to the science and technology concerns of these First World and Third World intellectuals would have seemed not only unrealistic but, more importantly, deeply unpatriotic. The Cold War was not a good time to articulate for Western ears skepticism about the empirical and theoretical adequacy or the political desirability of modern Western sciences and technologies. Perhaps today, two decades after the end of such relations between the First and Second Worlds, we are ready to move beyond a Cold War mentality.

To be sure, the antimilitarist and radical science movements that emerged in the United States and Europe during the Vietnam War did attract widespread attention, especially among the young in the 1960s. And ecology movements began to raise troubling questions about how Western sciences and technologies were affecting the environment. By the early 1970s, feminist movements were questioning the sexist biases of some of the most widely disseminated scientific theories, such as sociobiology, biological and medical theories about reproduction, and the assumptions about the environment that were the target of ecofeminists. Yet the message that most scientists, engineers, the educated public, and even university researchers and scholars took away from these claims and analyses was about the uses and abuses of scientific research. According to this view, these kinds of criticisms should focus on the politics in society, not on scientific and technical research itself. Such research could itself still be defended as value-free and committed to supposedly pure science and its basic research.

In the next section, I briefly describe this science-focused kind of postcolonial theory, or "postcolonial science theory," as I refer to it. The third section takes up another challenge for those who would create more reliable sciences that have the resources to advance democratic social relations in today's world. That challenge is the continuing persistence of damaging gender stereotypes that guide science policies and practices around the globe, including those of many advocates of postcolonial science theory. These gender criticisms, too, first emerged during the Cold War.[7] The third section looks at both the important assumptions that postcolonial and gender science and technology studies share, and the conflicting assumptions that prevent them from making good use of each other's most valuable insights. Now to the two main focuses of postcolonial science theory.

A POSTCOLONIAL THEORY FOR SCIENCE AND TECHNOLOGY STUDIES

As noted earlier, two issues were the focus of especially provocative questions from the beginnings of postcolonial science theory a half century ago. One was a historical question: what roles had Western sciences and technologies played in colonial histories, and what role had colonialism played in the histories of Western sciences and technologies? The other asked what the focus and character of science and technology policy should be in the newly independent Third World states. Attention to the second question had to focus also on aligning the policies and practices of the international and national aid agencies with the interests and desires of the poor people of the world rather than with only the interests and desires of the formerly colonial powers that now were the major funders of these programs. Many Western activists and researchers joined their Third World colleagues in working on this issue. As we shall see, the history and policy questions were linked. Their conjunction enables us to grasp the importance of thinking in terms of multiple modernities with their multiple sciences. Yet this recognition deeply challenges conventional Western epistemologies and philosophies of science, which have deep commitments to the existence of only one modernity and one real science.

History

Third World theorists found especially problematic the exceptionalist and triumphalist assumptions of the conventional Western views of science and technology in history. Exceptionalism assumes that the West alone is capable of accurate understandings of the regularities of nature and social relations and their underlying causal tendencies. There is one world, and it has a single internal order. One and only one science is capable of understanding that order. And one and only one society is capable of producing that science: our Western society! This was the logic of the exceptionalist view. It has reigned in philosophy of science as the unity-of-science thesis.[8] Triumphalism assumes that the history of Western scientific and technological work consists only of a parade of admirable discoveries and inventions. Any harmful events or processes in which scientific or technical achievements are accused of playing a role—such as Hiroshima, environmental destruction, global warming, militarism, or colonialism itself—were said to be caused by the ignorance and bad politics of political leaders and the public that they court. That is, such events or processes cannot be attributed to any features of modern Western sciences and technologies themselves. Those who make these assumptions find it unintelligible to claim that other societies can and have produced competent sciences or that it is reasonable to think that certain attributes of modern sciences themselves have made contributions to natural and social disasters.

Of course, ignorance and bad politics have all too often left their marks on history. But critics of exceptionalism and triumphalism think that ignorance and bad politics cannot be the end of the story. They have argued that a consequence of such assumptions is that Western sciences and technologies have seemed legitimately to escape the kind of postcolonial analyses and criticisms that have been so insightful about other Western institutions and practices. The postcolonial writings that became familiar in Western universities in the 1980s had little effect on such attitudes about sciences and technologies. This is so even though Edward Said, members of the Indian Subaltern Studies group, and other early post-colonial theorists clearly pointed to the role of Western sciences, technologies, and their philosophies in colonial projects.[9] This work also did not address the Cold War politics that had helped to put the very nature of modern Western sciences outside the range of reasonable criticism in university classrooms as well as by media in the West.

To be sure, a few scholars in the early days of the new social histories of science did use a postcolonial lens to produce counterhistories of Western sciences and technologies and their interactions with colonized societies.[10] However, as the field of social studies of science and technology began to develop during the Cold War, its historians, sociologists, and ethnographers tended to focus on how scientific facts were socially constructed in laboratories, and on how knowledge travels from one place to another. As Warwick Anderson points out, this interest in how knowledge travels aligns with globalization theory, not postcolonial theory. It makes issues about the past and present of colonial relations no longer relevant or even comprehensible.[11] Consequently issues about relations between sciences and technologies, on the one hand, and colonialism, imperialism, and their recent residues and resurrections, on the other hand, have until recently remained largely unaddressed in science and technology studies, as well as in academic postcolonial studies.[12]

History and Policy

By the mid-1980s, UNESCO and other international agencies, as well as regional institutes in the Third World, were sponsoring large multinational conferences on the issues raised by postcolonial science theorists, mostly but not entirely from the Third World. From the perspective of North

American science and technology theory writings, it is hard to get a sense of the huge number of scholars, policymakers, and activists who participated in such projects, the rich institutional networks and resources that supported them, or the thoughtful and provocative character of their concerns. In the United States at least, the occasional appearance of activists in these debates, such as Vandana Shiva or Ashis Nandy, could not convey the extensive global networks and institutional supports for this kind of postcolonial science theory.

One can get a quick grasp of the nature and range of these inquiries and debates by examining the proceedings of three international conferences that were published from the mid-1980s to the mid-1990s. Here I can only briefly describe them. *The Revenge of Athena: Science, Exploitation, and the Third World,* edited by Ziauddin Sardar, published twenty-one of the many dozens of conference presentations given in November 1986 at a seminar titled "The Crisis in Modern Science" sponsored by the Consumer Association of Penang, Malaysia. The book is divided into three parts: "What's Wrong with Science?," "Science and Third World Domination," and "Third World Possibilities." Contributors to the collection include figures—now well known in the field—such as Vandana Shiva, Claude Alvares, Susantha Goonatilake, Seyyed Hossein Nasr, and Jerome Ravetz, as well as Sardar himself. In this volume as in the other two, many of the contributors are themselves scientists, engineers, or mathematicians. The conference's "Declaration on Science and Technology," subsequently republished as *The Crisis in Modern Science: A Third World Perspective,* by the Third World Network,[13] provides an extensive agenda for redirecting Third World science and technology projects to Third World needs and desires. As the authors argue, "Only when science and technology evolve from the ethos and cultural milieu of Third World societies will they become meaningful for our needs and requirements, and express our true creativity and genius. Third World science and technology can evolve only through a reliance on indigenous categories, idioms and traditions in all spheres of thought and action" (Third World Network 1993, 487).

A second example is the proceedings of an international colloquium titled "Science and Empires—a Comparative History of Scientific Exchanges: European Expansion and Scientific Development in Asian, African, American, and Oceanian Countries," which was held in 1990 in the unesco building in Paris. The colloquium was organized by the rehseis (Research on Epistemology and History of Exact Sciences and Scientific Institutions) group of the French National Center for Scientific Research (cnrs). The proceedings were published as *Science and Empires,* edited by Patrick Petitjean, Catherine Jami, and Anne Marie Moulin. The thirty-five essays are organized into two parts, "Problems about the Integration of Classical and Modern Science" and "European Scientific Expansion and Political Strategies." A number of First World scholars contribute papers, including the three editors, as well as Nancy Leys Stepan, Lewis Pyenson, and Michael A. Osborne.

Finally, another set of proceedings contains papers presented at a conference sponsored by orstom, the French science institute for research outside France, and unesco. The conference took place in Paris in 1994. Its theme was "Twentieth Century Sciences: Beyond the Metropolis." It featured presentations by a large number (perhaps more than half) of the approximately two thousand participants from the Third World and Europe: researchers and scholars, scientists and engineers, policymakers and activists.[14] Seven volumes, edited by Roland Waast, of about 150 of the many conference papers were subsequently published. They address a wide range of topics. For example, volume 6, *Sciences in the South: Current Issues,* has book parts titled "Sciences on the Periphery: Assessments," "Privatisation and Globalization," and "The Western Character of Science."

A World of Sciences

Postcolonial science and technology perspectives provide distinctive arguments for recognizing the nature and value of "a world of sciences"—that is, multiple scientific and technological traditions, each relatively well adapted to regional needs and interests, though never perfectly so. They are joined by work in modernity studies and by minority tendencies in Western science and technology studies itself.[15] Here the central argument is that modernization is not identical to Westernization, contrary to Western exceptionalist and triumphalist assumptions. Rather, most peoples around the world now live in societies that have separated from hunter-gatherer economic and political relations and from the feudal political economies from which the modern West slowly emerged. Moreover, the global reach of Western modernity's corporations, environmental destruction, and arms industries, not to mention its contributions to the production of pandemics, financial disasters, immigration, and refugees, permeates even societies that have received few or no benefits from Western modernity. Today every society lives in global modernity, even if only in the darkest corners of its most hideous effects. To be sure, dissemination from the West and from other societies also plays significant roles in creating all societies today, but so too do processes internal to each society, as was the case in the West. Moreover, the recipient society always changes what it borrows so that the new ideas, processes, or goods fit into the existing social order with minimum disruption.

Thus modernity is not only disseminated from the West to other societies. It is also produced independently within each and every society. Whether arriving from outside or inside a society—or, more likely, through negotiations between inside and outside—it must be "sutured" into existing economic, political, cultural, psychic, and material worlds. Thus modernity will always take on distinctive local features in its multiple regional appearances. Its epistemologies will be to some extent local.[16] And it always tends to appropriate and reshape to its own ends the social hierarchies that it finds. Feminist and postcolonial projects will always have to be multiple and distinctively local if they are to serve those escaping male-supremacist and Western-supremacist histories.

A number of the authors here think in terms of a world of sciences, each serving the economic, political, cultural, and psychic needs of its peoples. And all these sciences are in many kinds of interactions with each other; conflicts, negotiations, coalitions, appropriations, integrations of parts of one with the other, disseminations, and more.[17] The urge to integrate or assimilate other knowledge systems completely into modern Western sciences, leaving just one global knowledge system, should vigorously be resisted. This would continue the tragic destruction and suppression of fruitful cultural diversity in knowledge systems that has characterized Western colonialism and imperialism. Fortunately such tendencies toward a monological knowledge system are widely resisted at least in practice these days, as many of the essays will demonstrate. Developing epistemologies adequate to a world of sciences is at this point an uncompleted project.

Such theories of knowledge must confront the reality that the contrast between modernity and tradition that has been so important to modernization theorists is neither as clear nor as useful as modernization theorists imagined. In the postcolonial literatures, one can see the contrast blurred, undermined, or "worked"—manipulated and destabilized—in historical practices of Third World societies and in the West. For example, the modernization theorists argued that the policies they recommended would replace supposedly backward traditions with modern beliefs and practices. Yet modernization, whether in the hands of the neoliberal World Bank or of post-Marxian dependencia theory, simply appropriated and subjugated to its own ends traditional households, women's work, and traditional family relations in its nation-building practices (Catherine Scott). Essays on the importance of so-called indigenous knowledge to indigenous societies and to ours, as well as the complexity and sophistication of indigenous knowledge, undermine modernity's intellectual and pragmatic devaluation of such knowledge systems. South Pacific navigation (Goodenough) and Cree hunting practices (Colin Scott) provide good examples of such knowledge systems. Today advocates for traditional knowledge systems defend them by using modern electronic technologies (Warren) and legal contracts (Brush, Hayden). Some do insist on the importance of further integrating such systems into modern Western sciences (Goonatilake), and others advocate integrating selected elements of Western sciences and technologies into them (Hoppers, Sardar). Readers can identify additional ways in which both supposedly traditional and supposedly modern societies work the boundaries between the two categories.

I have mentioned women here and there. Yet it would be a mistake to think that *gender* refers only to women. What is gender? How have gender issues shaped sciences and technologies in colonial, imperial, and postcolonial contexts? What resources can feminist (or gender) studies of science and technology provide for improving research and democratizing global social relations?[18]

GENDER AND POSTCOLONIAL SCIENCE AND TECHNOLOGY STUDIES: SEPARATE, CONJOINED, OR COCONSTITUTED PATHS?

No Women, So No Gender Issues?

The conquistadors, explorers, missionaries, merchants, indigenous rulers, scientists, historians, anthropologists and their informants, and theorists of modernity and development, as well as the leading scholars who contribute to postcolonial science and technology studies—these have been mostly men. Consequently some scholars seem to think there is little reason to raise gender issues in addressing topics in this field. Many assume that gender issues are relevant only if women are in sight, or perhaps even only if one is actually studying women. Yet the assumption that gender refers exclusively to women is false. It undermines the reliability as well as the legitimacy of accounts guided by it. In contrast, recent studies have found ways to ask how the very absence of women has influenced the selection of scientific problems, the methods of research and the regulatory ideals that guide them, what count as scientific communities, conceptions of natural processes, the interpretation of data, the results of research, and the dissemination of scientific applications and technologies, as well as at least some prevailing understandings of nature's order. In societies organized by male-supremacist gender hierarchies, men, their ideas and practices, cannot be unique models of the human. They can only mark historically specific masculine examples of the human.

The field of feminist science and technology studies has been developing in the global North and South since the 1970s. Yet this work and postcolonial science and technology studies too often ignore each other. The assumption that gender and postcolonial paths are separate damages the reliability and progressive promise of each.[19] Arguments for their "intersection" are preferable, and they have been useful in confronting the race and gender blindness of U.S. law (Crenshaw et al. 1995). However, this metaphor retains the false idea that somehow gender relations and colonial relations were at one time both functioning, and yet were separate from each other before they "intersected." That assumption could be made only by people privileged by their position in gender and colonial hierarchies. For colonized women, differences in their lives from the conditions of men, as well as from the conditions of their colonial rulers, are part of their everyday lived experiences. Here the argument will be that gender and colonial relations have coconstituted each other.

Gender and Postcolonial Science and Technology Studies: Weak and Strong Complementarity

The agendas of feminist and postcolonial science and technology studies are similar in important respects and thus would seem to be complementary.[20] For example, both argue that the perspectives and interests of their particular constituencies are not well served by modern Western science and technology policies, practices, or philosophies. To be sure, modern Western policies, practices, and philosophies of science and technology have delivered some benefits to some women in the West. Yet these sciences and technologies were not designed to respond to any group of women's needs and desires in the West, let alone to the distinctive needs and desires of women in different classes, races, ethnicities, and cultural groups around the globe. They have been designed to respond primarily to the needs of states, militaries, and corporations, from the design and management of which women have systematically been excluded. Women (as well as most men) around the globe have borne disproportionate shares of the costs and received relatively fewer of the benefits of modern Western sciences and technologies.

Moreover, both offer alternatives that they claim are grounded in more realistic understandings of knowledge production processes, are more comprehensive, and can better serve the peoples for whom each speaks. Thus the agendas of each are always explicitly political as well as intellectual.

Additional reasons for each to be interested in the projects of the other can come from recognition that their constituencies are overlapping and their discourses are interlocked. More than half of the formerly colonized and those still under the control of neocolonialism and neoimperialism are women. Additionally, children and the elderly, disabled, and sick depend on women for their daily survival. To put the point the other way, a huge majority of the world's women and their dependents are among formerly colonized peoples and those now negatively impacted by residues and resurrections of colonialism and imperialism.

Furthermore, the dominant discourses that these social movements criticize, as well as the ones they themselves use, are deeply imbricated or locked into each other: colonialism, imperialism, and male supremacy have persistently represented gender in racial or colonial terms, and racial and colonial relations in gender terms (e.g., Stepan 1986). Women supposedly are not fully civilized, and non-Western men are supposedly not as manly as are men of European descent. Nor are women and non-Western men regarded as capable of managing their own lives as well as are men of European descent, according to such views.

Gender and racial-colonial categories still coconstitute each other today (Catherine

Scott). Thus, because of their overlapping constituencies and interlocking discourses, each of these science and technology movements would seem to have to depend on the successes of the other to achieve its own professed goals. In this sense, they are *strongly complementary.*

Yet these two science and technology movements often seem committed to conflicting assumptions about the relevant social relations, the relevant sciences, and questions of who can and should be agents of the kinds of radical social and scientific change for which each calls. (There are important exceptions to this charge.) Under such circumstances, neither social movement can deliver the benefits it envisions to the majority of those to whom it has professed accountability. So what are the contributions that gender and postcolonial studies of science and technology can make to each other's projects? Before we turn to this issue, it is worthwhile to recollect just what gender is and is not. In feminist work, the *gender* is used in ways that may not be obvious.

What Is Gender?

Gender is not another word for women. Rather, like class and race, it designates particular kinds of social relations, here between men and women as well as between men and between women. These relations are "made, not born," to borrow from Simone de Beauvoir's famous observation. Moreover, gender relations are manifested not only by individuals but also in the structures and systematic practices of institutions (e.g., job classifications, legal regulations). They also appear in our symbolic systems, our meanings, as when nations are represented as women (Liberty, Columbia, Marianne) or when regulative ideals of research, such as objectivity and rationality, are represented as requiring a distinctively masculine character. Furthermore, gender relations organize hierarchical institutional structures of economic, political, and social power. However, gender never functions alone; it always interacts with other powerful social relations, such as race and class. Whether one conceptualizes such interactions as intersections or as processes of coconstitution, gender relations are always historically dynamic. Finally, like race and class, *gender* is both a descriptive and an analytic term. It designates both something "out there" in social relations and also a kind of analytic framework invoked to explain diverse manifestations of such social relations.[21]

Gender and Science Studies

This field is by now four decades old. I will not review that history here except to name five focuses of ongoing concern in the North, as well as everywhere that Northern sciences have found a home in the South (though there are additional gender issues in the South). Such projects have been initiated by groups with different kinds of disciplinary, political, and institutional interests in scientific and technological research. One such question is where women in the social structures of modern sciences are (and have been), and why there have been so few of them in the arenas of the design and management of research. Another is how and why "sexist sciences" have provided empirical support for the claimed inferiority of women. A third asks how technologies and the applications of the results of scientific research have been used against women's equality. Women's health, reproductive, and environmental concerns were among the earliest such focuses here. Fourth, how do scientific and technical education—pedagogy and curricula—restrict girls' and women's (and boys') development as scientists and engineers?[22] Finally, what is problematic about the epistemologies, methodologies, and philosophies of science that produce and support such sexist and androcentric practices?[23]

Such issues all remain important almost four decades after they were first posed—unfortunately. Some areas show significant progress—for example, in increasing access for women to scientific educations, publications, organizations, and lab and classroom jobs, and in establishing at least token presences of women in policy contexts. Moreover, significant changes in health and reproductive policies have occurred for women in already advantaged groups. Some feminist epistemological and methodological work has enabled new kinds of increasingly widespread debates about the relation of different human experiences to the production of knowledge. Yet women in Africa, Asia, and other places around the globe, as well as poor women in the West, have not much benefited from these kinds of progress.

However, neither postcolonial nor Northern feminist science and technology studies are likely to improve women's conditions as long as their fundamental assumptions conflict. From the perspective of Northern labs, science curricula, and federal policy, it is all too easy to be unaware of how Northern sciences and technologies function globally. In none of such contexts can one easily focus on postcolonial or gendered social relations, indigenous knowledge or feminist research innovations, or the possibility that Northern residents, men or women, will probably not be the most valuable agents of democratic social change in science and technology worlds. What are these conflicting assumptions made by feminist and postcolonial science and technology studies?

Theoretical and Methodological Sites of Dissonance

First, what are the relevant social relations to be examined for these two kinds of science and technology studies? Postcolonial science and technology scholars who are men rarely see gender relations as relevant either to the situations they observe or to their own theoretical or empirical concerns. Similarly, far too few Western feminists have focused on post-colonial science and technology relations. The exceptions here are to be found primarily in the long history of criticisms of science and technology aspects of development policies and practices and in environmental studies.

More than three decades ago, historians pointed out that recognizing women to be fully human—as fully human as their brothers—undermines traditional theoretical and methodological assumptions about social relations. This recognition raises provocative questions. For example, how should we account for the fact that women's conditions have tended to regress at precisely the moments marked in conventional histories as high points of human progress, such as the Renaissance, or the state formation resulting in Athenian democracy and, more than two millennia later, the United States? Even worse, it turns out that it was precisely because of the features identified as progressive that women's lives regressed. This is because whatever is extolled as progressive tends to be symbolized as virile and manly in societies structured by gender hierarchy. For example, it was not an accident that in the Renaissance women lost rights and opportunities that they had earlier possessed. Moreover, in state formation, women have invariably lost legal and political rights they had possessed in earlier periods, including the democratic revolutions of eighteenth-century Europe and the independence movements of newly postcolonial states after World War II (Kelly-Gadol 1976; Pateman 1988; Catherine Scott). Apparently conventional theories of social change have failed to account for the transformations they intend to chart insofar as they ignore women's role and fate in such processes. It has become clear that chronologies grounded only in what happens in men's lives, whether about the North or the South, leave no conceptual space for significant changes in women's lives or for examining the effects that the conditions of women's and men's lives have had on each other.

Yet postcolonial science and technology studies seem to assume that women and men benefit equally from men's progress, and that gender relations are irrelevant to the most adequate theories of social change. With important exceptions, the relevant social relations in the accounts of postcolonial science and technology studies are those of presumably gender-free imperialism, colonialism, nation building, and the local, apparently gender-free acquiescences or resistances to such processes. Occasional references to "women's concerns" do not address gendered social structures or symbolic practices, let alone feminist epistemologica, methodological, or philosophy of science issues. Consequently postcolonial theory cannot understand colonial, imperial, postcolonial, or today's neocolonial and neoimperial processes as long as its assumptions obscure women's realities and experiences, their standpoints on dominant social relations, and the gender relations that structure and give meaning to social institutions and the men's and women's lives lived within them. Important exceptions here that are focused on science and technology issues include the work of Anne Fausto-Sterling (1994, 2005), Donna Haraway (1989, 1991), and Vandana Shiva (1989).

It is encouraging to see that a few historians and ethnographers have begun to identify the gendered symbolic meanings and accompanying practices that have shaped Western sciences and technologies in colonial and imperial projects. For example, they have focused on scientists' claims that the greatest scientific value should go to the discoveries and inventions produced though the manly heroism of scientific quests (Terrall); on the gender, class, and colonial structure of Jesuit scientific communities in their overseas missions (Harris 2005; Rhodes 2005); on the masculine chivalric values of the knowledge gathering by Spanish conquistadors as well as British and French colonialists (Canizares-Esguerra 2005); and on the application of gender stereotypes to colonial relations in typical British representations of fitness and disease in the colonies (Harrison 2005). This is an area ripe for further exploration.

In a parallel way, much Western feminist work only rarely sees the social relations of colonialism and imperialism as having anything to do with women's or men's experiences of Western scientific and technological work. These scholars seem to think that as long as they are focused only on Western women and gender relations, social relations of colonialism and imperialism are irrelevant to the sciences and technologies they observe. Such assumptions leave us all ignorant both of the history and practices of sciences and technologies around the globe and of women's and men's variable participation in, and experiences of, such histories and practices. Thus similar arguments about treating non-Westerners as fully human reveal the limitations of traditional Eurocentric methodology in Western feminist science and technology studies—one that is shared, for the most part, with the larger field of science studies. Each field ignores powerful kinds of social relations that have shaped the content of sciences and technologies.

A second site of dissonance is the question of what the relevant sciences are for these two kinds of studies. For Western feminists (like Western science studies more generally), these have been almost entirely modern Western ones.[24] Courageous and brilliant work has been accomplished here in addressing the gender dimensions even of the sciences thought least susceptible to social fingerprints, such as physics and chemistry (Keller 1984; Potter 2001; Traweek 1988). Yet the history of modern Western sciences and analyses of their practices today are almost never set in the context of the history of Western appropriation of significant achievements of other cultures' sciences and technologies, or of Western destruction of them. Indigenous knowledge traditions, whether in the West or elsewhere, seem for the most part to be beyond the horizons of most of this work. Western feminist work, like much of the larger science studies movement in which it is embedded, is unaware of the counter-histories, the successes of indigenous knowledge, or the arguments for valuing multiple science traditions—a world of sciences. These kinds of studies call for radically rethinking conventional Western assumptions about scientific rationality and technical expertise. Consequently, the view of modern Western sciences and technologies from the standpoint of non-Western societies is also missing from Western feminist science and technology studies.[25]

Indigenous traditions, critical perspectives on modern Western sciences, and the design of science and technology policies and practices that integrate the best of both worlds are central projects for postcolonial scholars. They have produced diverse evaluations of these different traditions and accounts of possible future relations between indigenous and modern Western scientific knowledge systems.[26] Yet there has been little focus on women's domains of producing knowledge in these accounts of indigenous knowledge, and little awareness of the different kinds of experiences women have (different in different cultural contexts, but also different from men's in such contexts) that have informed Western feminism's innovative methodological and epistemological strategies. Nor have postcolonial science and technology scholars grasped the limitations of their own analyses and recommendations from the standpoint of women's interests. They have not treated women, their needs, interests, and insights, as fully human, nor have they considered them as equally crucial to social progress as they consider their own. Often feminism is perceived by men in formerly colonized societies as a Western import. In these cases, resistance to feminism is perceived to be an important part of resistance to Western imperialism. And this is so in spite of often vigorous and innovative feminist movements created locally by their female colleagues and compatriots. Evidently these otherwise brilliant intellectuals and activists take women to be more easily duped by the West than are men.[27]

Finally, the feminist and postcolonial accounts disagree on questions of who can and should be the agents of progressive transformations of societies and their sciences. Neither movement seems to think it necessary to center members of the other group in the envisioned design and management of its projects. Only a few women, such as Donna Haraway and Vandana Shiva, appear in the citations of contemporary postcolonial science studies scholars, and these are mostly the same few who appear occasionally in the feminist work.[28] The standpoint of women only rarely makes an appearance in this postcolonial work. Similarly, the standpoint of poor people in the Third World is missing from many Northern feminist analyses. Moreover, non-Western peoples do not appear as the designers or leaders of radical political and intellectual transformation in most Western feminist work. Other voices are hardly ever heard or reported except occasionally as special interests. That is, the others are never represented as being at the forefront in conceptualizing or leading social action toward goals and strategies that will produce widespread benefits, including but not limited to those purportedly special-interest groups themselves.[29]

Neither movement can deliver social progress to its professed constituencies without attending to the full range of issues addressed by both postcolonial and feminist science and technology studies. The existing separation of these two powerful conceptual frameworks must be ended.

The preceding section focused on one especially challenging contribution that postcolonial science theorists have made to global thinking about sciences and technologies. This is the conception of a world of sciences; that is, a world of multiple modern sciences, each with distinctive achievements, and each often in conflict with other scientific traditions. Western science studies itself has recently produced a similar account focused entirely on modern Western sciences (Galison and Stump 1996; Kellert, Longino, and Waters 2006). Here we turn to just one of the compelling and yet provocative contributions to rethinking regulative ideals of scientific research made by feminist science studies.

Standpoint Methodology

This way of designing and conducting research projects has been theorized most extensively with respect to gender issues, though its logic is also usually invoked in postcolonial accounts, as it is in many other social justice research projects (Harding 2004b). The concept of a methodological standpoint arose in Marxian writings about the importance of taking the "standpoint of the proletariat" to understand how capitalism actually worked, contrary to the bourgeoisie's continual justification of the necessity of exploiting manual laborers. So this geographical metaphor directs attention to a location, a site in social relations, from which a disadvantaged group learns to observe and speak *for* itself and to the advantaged group about how unjust and oppressive social relations affect their lives. By starting off thought from the daily lives of workers, one could explain the otherwise mysterious phenomenon of how wealth accumulated in the lives of the already advantaged while misery accumulated in the lives of the workers. One could do so without appealing to the typical biological, religious, social, or political justifications for such inequalities that were promoted by the ruling groups of the day (and still in our neoliberal days).

Of course there are many problems with using such Marxian theory today. Nevertheless the basic insight of this research methodology—its logic—has remained useful to many disadvantaged groups around the globe. In feminist hands, the standpoint strategy directed researchers to begin thinking about any and every project from the standpoint of women's lives instead of from the conceptual frameworks of research disciplines or of the social institutions that such disciplines serve. Women had been excluded from the design and management of these disciplines and institutions. Those frameworks had been designed to answer questions that were *for* the dominant social groups, not *for* women or other exploited groups. The dominant institutions sponsored, funded, and monitored research in the natural and social sciences; their policies were grounded in gender stereotypes. They promoted the "conceptual practices of power," in the words of Dorothy Smith (1990).

Standpoint projects "studied up" (as the Marxists put it). They began by thinking about the dominant institutions, their practices and cultures, from the standpoint of the women's lives affected by them. Their goal was not to produce ethnographies of women's worlds, valuable as those can be. Rather, they intended to explain the high-level institutional decisions and practices responsible for initiating and maintaining such situations. In this respect, they differed from the ethnographies that were frequently parts of such projects and with which they were often mistakenly conflated.[30] Standpoints are not to be conceptualized only as perspectives. Everyone has perspectives on the world, but standpoints are intellectual and political achievements in that a group has to work together to figure out how to arrive at them. They require critical, scientific study to see beneath the everyday social relations in which all have been forced to live. They also require political struggles to gain access to the sites (the boardrooms, the command centers, the policy circles) where one could see how decisions have been made that directed and maintained sexist and androcentric social relations (Hartsock [1983] 2003).

Standpoint theory produced stronger standards for good method in the natural as well as the social sciences. Similarly, it produced revisions of other regulative ideals of the sciences, including "strong objectivity" and "robust reflexivity," and produced more rigorous and comprehensive standards for rationality (Haraway 1991; Harding 2004a, 2004b). Standpoint methodologies have by now explicitly been adopted across the social sciences, in some mixed social and natural sciences such as environmental and health studies, in several areas of biology, and in some technology studies. Moreover, the logic of such methodologies has an organic quality in that it seems to appear whenever a disadvantaged group tries to articulate the legitimacy of its own knowledge needs against the research practices that serve powerful groups. Thus the logic of standpoint epistemology and methodology is routinely evoked in postcolonial writings that start off from the lives of Third World peoples to think about Western assumptions, policies and practices, and indigenous knowledge systems; or about encounters with European voyagers, botanists, and physicians; or about modernization or development theory.

One can still ask, however, if standpoint methodology and epistemology are too Western to be fully useful elsewhere. Standpoint theory was initially formulated within the Marxian and Enlightenment philosophical and methodological traditions, even as it protests significant aspects of such legacies. Although it is positioned against both positivist regulatory ideals and practices in Western-origin natural and social sciences, positivism is not, to take just one case, one of the most problematic aspects of Indian society for women, as the philosopher Urna Narayan pointed out several decades ago. Moreover, standpoint theory's appeal to the value of women's experience can lose its critical edge in societies that conceptualize sex and gender differences as fundamentally complementary rather than hierarchical, and this is so regardless of whether such differences are in fact treated as hierarchical (Narayan 1989). There are other ways, with significant relations to standpoint theory, to articulate research methodologies that can distribute their benefits more effectively to the least advantaged groups.[31]

Yet standpoint theory remains a valuable strategy to articulate the logic of "a space of a different kind for polemics about the epistemological priority of the experience of various groups or collectivities," as Fredric Jameson put the point. "The presupposition is that, owing to its structural situation in the social order and to the specific forms of oppression and exploitation unique to that situation, each group lives in the world in a phenomenologically specific way that allows it to see, or better still, that makes it unavoidable for that group to see and know, features of the world that remain obscure, invisible, or merely occasional and secondary for other groups" (Jameson 2004).[32] Standpoint approaches can recognize the positive scientific and political value of local knowledge without falling into claims either of its absolute, universal validity and applicability or of its legitimacy by only local standards. That is, standpoint approaches do not commit their users either to problematic older positivist regulative ideals or to a mere relativism of claims valid only in their local context. It is a symptom of the originality of this approach that so many readers can't resist interpreting it only as either absolutist or relativist in a damaging way. Yet, it is only from the perspective of the absolutists exceptionalist position that these do appear to be the only choices.

PROVOCATIONS AND ILLUMINATIONS

This essay explored two theoretical frameworks that can illuminate some of the most puzzling and provocative intellectual and political challenges of the day. Sciences (and technologies) and their societies coconstitute each other. Each provides resources for the development of the other—and this can occur whether such development is politically and intellectually progressive or regressive. This insight supports postcolonial and feminist arguments that sciences and technologies are never completely value-free. How should we think about the virtues of modern Western sciences and technologies in light of these challenging views of them? How should we think about the knowledge systems of other cultures? How should we think about many non-Western sciences and technologies that today function effectively for cognitively valuable and politically admirable projects in their own world and yet still do not address women's needs where these differ from men's? What about those that do and must function in a modern world but find themselves in some of the most deprived locations in that world?

By now it should be clear that there cannot be a single recipe for science and technology research projects that are desirable from feminist and postcolonial standpoints. We can at least agree that we should not support one that conforms to the traditional Western conception of progress and how to achieve it. Women and men in different eras and places experience differently the nature and effects of colonialism, imperialism, post-colonialism, neocolonialism, and the sciences and technologies that these social relations create. Cultures have their own distinctive histories, legacies, resources, values, and interests, and it is the cultures themselves that must create discussions of how best to plot their own futures (with certain caveats about harming others and their own most vulnerable members, of course). Thus it would be arrogant and ineffective for any one culture to take it upon itself to determine what will be best for all, and especially for Western researchers and scholars to do so for non-Western societies. There already are and must be many different kinds of epistemologica, scientific, and technological struggles over priorities, goals, and strategies.

Meanwhile our natural and social environments themselves constantly change. They continually produce unexpected phenomena such as retroviruses, ozone holes, and global warming, as well as deadly financial crises, hurricanes, fires, and mudslides. Our daily environments now seem crowded with risks to life and health that were not imagined even one generation ago (Beck 1992). Westerners have to learn how to live with not knowing how such relations between knowledge systems and with natural and social orders will turn out. The vitality of both nature and global tendencies toward democracy in all their local varieties depends on our learning to tolerate—even thrive—in the face of continually appearing uncertainties (Sarewitz). In this kind of world, postcolonial and feminist science and technology studies can help us locate innovative strategies for moving forward, not only by considering their illuminating but provocative challenges to conventional assumptions but also by exploring the alternatives that they are debating.

NOTES

1. The language I use here of West and non-West is problematic. It echoes the discredited Orientalism that makes the West the center of geography, history, and critical analyses and is one of the founding targets of postcolonial criticism. It obscures the fact, addressed in many essays here, that the West consistently appropriated scientific and technological insights and achievements of other societies for its own projects, to this day almost always without acknowledgment, It occludes the difficulty of fitting into this binary the science and technologies of many societies around the world that have developed their own forms of modernity. See, e.g., Eisenstadt 2000; Mignolo 2000; Rofel 1999.

   Moreover, all the available alternative contrasts are also problematic: First World-Third World (an artifact of the Cold War), "developed-underdeveloped" (who defines this difference?), and more. Furthermore, any such contrast inaccurately homogenizes the two groups and obscures the more complex social relations that exist between and among various global groupings in the past and today, reifying a preoccupation with differences that hides shared interests and practices between peoples in very different social circumstances. Some authors prefer to discuss today's global social relations in supposedly more politically neutral language such as "globalization" or "transnationalism." Such terms can be useful in some contexts. They are not politically neutral, however, for they hide power relations that are the focus of this book's contributors. In light of such difficulties with alternatives, I continue here to use primarily "West–non-West" and, where appropriate, shift to "First World–Third World" or "North–South" when those terms better indicate the relevant context.
2. See Seth 2009b for these and many more citations to the rich history of anticolonial counterhistories of science to the standard Western ones.
3. The term *postcolonial* is highly contested, even within the field of post-colonial studies. Who and what is, and should be, included or left out of its domain? Is it by now archaic—an artifact of the 1980s that is no longer useful? I do not take the space to review such issues here. My own view is that the term has by no means exhausted its progressive possibilities, though its limitations, addressed in a number of the essays here, are important to ponder. For just three of the many illuminating discussions about the usefulness and desirable domains of the concept of postcolonialism, see Goldberg and Quayson 2002; Loomba et al. 2005; and early issues of the journal *Postcolonial Studies.*
4. For fuller discussions of these histories, see Seth 2009b; Anderson 2009; Anderson and Adams 2007.
5. Anderson 2002; McNeil 2005; Schiebinger 1989.
6. Discussions with Gail Kligman helped me see the importance of the Cold War in masking for Westerners the work of Third World science and technology intellectuals.
7. This may suggest some reasons in addition to sexism for the hysterical demonization the feminist theorists frequently encountered. However, one could argue that the manliness of the militaries certainly was at issue in the Cold War, as it is in every war. Readers "of a certain age" will remember how the newspapers' front pages regularly featured charts depicting two piles of missiles. Representing the West's arms capabilities would be a large pile of big, white missiles; representing the Soviet capabilities would be a small pile of little black ones. The apparent innocence of bygone eras can be startling.
8. The unity-of-science thesis persists today in spite of such philosophers' criticisms, e.g., Dupre 1993; Galison and Stump 1996.
9. Ashcroft, Griffiths, and Tiffin 1989, 1995; Williams and Chrisman 1994.
10. See, e.g., Adas 1989; Blaut 1993; Brockway 1979; Headrick 1981; McClellan 1992.
11. Anderson 2009. An exception to this judgment is the work of Helen Watson-Verran and David Turnbull (1995).
12. As noted earlier, historians of science and medical anthropologists have long examined the knowledge systems of other cultures, though much of this work does not deserve to be called postcolonial. The postcolonial work in these fields has tended to be written for, and to remain primarily the concern of, specialists.
13. Excerpted in Harding 1993.
14. I could identify only a dozen presenters from North America.

15. See, e.g., Eisenstadt 2000; Maffie 2009; Galison and Stump 1996.
16. Several contributors to this collection discuss "polycentric" or "polyvocal" epistemologies. For just a few of the many new explorations of distinctive non-Western modernities, see also Mignolo 2000; Ong and Nonini 1997; Shih, forthcoming; Lionnet and Shih 2005; Rofel 1999; Chakrabarty 2000; Eisenstadt 2000; Harding 2008; Prakash 1999.
17. See, e.g., many of the chapters in parts II and IV of this collection.
18. There is no uncontroversial term to refer to this kind of research. *Feminist* is too radical a term for many Westerners who, assisted by persistent media demonization of women's movements, associate the term only with the most ambitious and theatrical parts of the Western women's movements of the 1970s. On the other hand, *feminist* is a conservative term for many people in the United States and around the world who associate it with bourgeois women's rights movements that have had little concern for the lot of poor women, African American women, and other women of color. However, so-called gender studies can seem to lack any awareness of inequalities between men and women, or even between men or between women. I shall alternate between these two inadequate terms, hoping to offend only half of the readers at any given time.
19. This is not to deny either that gender relations vary immensely from one culture to another, as do colonial relations, or that in some colonial contexts gender may not always be the most important variable on which to focus.
20. An early form of the rest of this section appears in Harding 2009.
21. Two comments. First, the insistence on separating the social gender differences so firmly from the biological relations of sex differences may well be on shaky ground. This is not because biological reductionism was right (it wasn't) but because the binary of gender versus sex is a form of the culture-versus-nature binary that has come under severe criticism in several branches of biology (Fausto-Sterling 1994; Keller 1984). Moreover, the culture-versus-nature binary is no longer legitimate in science studies where cultures and their concepts of nature are seen as coconstituting each other. Nor do other cultures' knowledge systems tend to find it appropriate. The solution is to be found in inventing a new kind of biology that does not depend on such a severe separation between the social and the natural, but this we do not yet have. Second, it is also worth thinking about the effects of transgender and transsexuality theories and practices on ways of analyzing gender differences (Valentine 2007).
22. These studies can appear to focus only on women, but they have always been concerned with how economic, political, and social gender inequality unfairly limited women's interactions with sciences and technologies while overadvantaging men's interactions, and with how women resisted such discrimination. It is not so much that men are perceived to be the problem for women. Rather, the social institutions that exclusively men have designed and managed do not serve women's interests and desires well.
23. Examples of this relatively early work include Boston Women's Health Collective 1970; Fausto-Sterling 1994; Haraway 1989; Harding 1986, 1991; Harding and Hintikka [1983] 2003; Hubbard, Henifin, and Fried 1982; Keller 1984; Longino 1990; Merchant 1980; Rossiter 1982–95; Schiebinger 1989, 1993; Tobach and Rosoff 1978–84; Wajcman 1991. The medical establishment's disparaging and often erroneous opinions about women's bodies were the object of much early gender and science work. For recent reviews of these issues, see Harding 2008, chap. 4; and Subramaniam 2009.
24. See, e.g., the otherwise excellent, widely used reader for gender and science studies courses, Wyer et al. 2001.
25. My argument is not that the feminist theorists themselves are unaware of these matters but that the theoretical and methodological frameworks that they deploy obscure or marginalize such issues.
26. See, e.g., Denzin, Lincoln, and Smith 2008; Goonatilake 1984; Hess 1995; Hoppers 2002; Nader 1996; Third World Network 1993; Turnbull 2000; Watson-Verran and Turnbull 1995.
27. I am being a bit disingenuous here. Men in every society have resisted giving up their gender privileges. They usually mask their interests in male supremacy with arguments about the trivial or dangerous nature of any challenges to their control over women's lives. This is so even when they have good reasons to resist continued Western intrusions in their societies. Arriving at the best strategies for overcoming inequalities at least requires a lot of public dialogue between all the relevant stakeholders.
28. Many more appear in the larger field of postcolonial studies. Moreover, many additional significant postcolonial feminist science and technology scholars are working in the West and around the world. See those included in this collection, and the many citations throughout this book.

29. Poor people and grassroots activists from around the globe tend to have what they understandably see as more urgent projects than to write essays or books to be published in the West. But there are many other ways for their voices to be heard in the West, as many of the essays here demonstrate.
30. But see D. Smith 2005 for a critical institutional ethnography.
31. See, e.g., Anzaldúa 1981; and Walter Mignolo's articulation of the "colonial difference" (2000).
32. For a highly visible polemic about a standpoint claim, see the discussion of the U.S. Supreme Court (at that time) candidate Sonia Sotomayor's statement in a speech some years earlier that she hoped a wise Latina would make better decisions in some cases than a wise white man (*Los Angeles Times* 2009a, 2009b, 2009c).

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SECTION V

Theoretical Horizons in Feminist Technoscience Studies

CHAPTER 27

Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective[1]

Donna Haraway

Academic and activist feminist enquiry has repeatedly tried to come to terms with the question of what *we* might mean by the curious and inescapable term 'objectivity'. We have used a lot of toxic ink and trees processed into paper decrying what *they* have meant and how it hurts *us*. The imagined 'they' constitute a kind of invisible conspiracy of masculinist scientists and philosophers replete with grants and laboratories; and the imagined 'we' are the embodied others, who are not allowed *not* to have a body, a finite point of view, and so an inevitably disqualifying and polluting bias in any discussion of consequence outside our own little circles, where a 'mass'-subscription journal might reach a few thousand readers composed mostly of science-haters. At least, I confess to these paranoid fantasies and academic resentments lurking underneath some convoluted reflections in print under my name in the feminist literature in the history and philosophy of science. We, the feminists in the debates about science and technology, are the Reagan era's 'special interest groups' in the rarefied realm of epistemology, where traditionally what can count as knowledge is policed by philosophers codifying cognitive canon law. Of course, a special interest group is, by Reaganoid definition, any collective historical subject which dares to resist the stripped-down atomism of Star Wars, hypermarket, postmodern, media-simulated citizenship. Max Headroom doesn't have a body; therefore, he alone *sees* everything in the great communicator's empire of the Global Network. No wonder Max gets to have a naïve sense of humour and a kind of happily regressive, pre-oedipal sexuality, a sexuality which we ambivalently—and dangerously incorrectly—had imagined was reserved for lifelong inmates of female and colonized bodies, and maybe also white male computer hackers in solitary electronic confinement.

It has seemed to me that feminists have both selectively and flexibly used and been trapped by two poles of a tempting dichotomy on the question of objectivity. Certainly I speak for myself here, and I offer the speculation that there is a collective discourse on these matters. On the one hand, recent social studies of science and technology have made available a very strong social constructionist argument for *all* forms of knowledge claims, most certainly and especially scientific ones.[2] In these tempting views, no insider's perspective is privileged, because all drawings of inside–outside boundaries in knowledge are theorized as power moves, not moves towards truth. So, from the strong social constructionist perspective, why should we be cowed by scientists' descriptions of their activity and accomplishments; they and their patrons have stakes in throwing sand in our eyes. They tell parables about objectivity and scientific method to students in the first years of their initiation, but no practitioner of the high scientific arts would be caught dead *acting on* the textbook versions. Social constructionists make clear that official ideologies about objectivity and scientific method are particularly bad guides to how scientific knowledge is actually *made*. Just as for the rest of us, what scientists believe or say they do and what they really do have a very loose fit.

The only people who end up actually *believing* and, goddess forbid, acting on the ideological doctrines of disembodied scientific objectivity enshrined in elementary textbooks and technoscience booster literature are non-scientists, including a few very trusting philosophers. Of course, my designation of this last group is probably just a reflection of residual disciplinary chauvinism from identifying with historians of science and too much time spent with a microscope in early adulthood in a kind of disciplinary pre-oedipal and modernist poetic moment when cells seemed to be cells and organisms, organisms. *Pace,* Gertrude Stein. But then came the law of the father and its resolution of the problem of objectivity, solved by always already absent referents, deferred signifieds, split subjects, and the endless play of signifiers. Who wouldn't grow up warped? Gender, race, the world itself—all seem just effects of warp speeds in the play of signifiers in a cosmic force field. All truths become warp speed effects in a hyper-real space of simulations. But we cannot afford these particular plays on words—the projects of crafting reliable knowledge about the 'natural' world cannot be given over to the genre of paranoid or cynical science fiction. For political people, social constructionism cannot be allowed to decay into the radiant emanations of cynicism.

In any case, social constructionists could maintain that the ideological doctrine of scientific method and all the philosophical verbiage about epistemology were cooked up to distract our attention from getting to know the world *effectively* by practising the sciences. From this point of view, science—the real game in town, the one we must play—is rhetoric, the persuasion of the relevant social actors that one's manufactured knowledge is a route to a desired form of very objective power. Such persuasions must take account of the structure of facts and artefacts, as well as of language-mediated actors in the knowledge game. Here, artefacts and facts are parts of the powerful art of rhetoric. Practice is persuasion, and the focus is very much on practice. All knowledge is a condensed node in an agonistic power field. The strong programme in the sociology of knowledge joins with the lovely and nasty tools of semiology and deconstruction to insist on the rhetorical nature of truth, including scientific truth. History is a story Western culture buffs tell each other; science is a contestable text and a power field; the content is the form.[3] Period. The form in science is the artefactual-social rhetoric of crafting the world into effective objects. This is a practice of world-changing persuasions that take the shape of amazing new objects—like microbes, quarks, and genes.

But whether or not they have the structure and properties of rhetorical objects, late twentieth-century scientific entities—infective vectors (microbes), elementary particles (quarks), and biomolecular codes (genes)—are not Romantic or modernist objects with internal laws of coherence.[4] They are momentary traces focused by force fields, or they are information vectors in a barely embodied and highly mutable semiosis ordered by acts of recognition and misrecognition. Human nature, encoded in its genome and its other writing practices, is a vast library worthy of Umberto Eco's imagined secret labyrinth in *The Name of the Rose* (1980). The stabilization and storage of this text of human nature promise to cost more than its writing. This is a terrifying view of the relationship of body and language for those of us who would still like to talk about *reality* with more confidence than we allow the Christian right's discussion of the Second Coming and their being raptured out of the final destruction of the world. We would like to think our appeals to real worlds are more than a desperate lurch away from cynicism and an act of faith like any other cult's, no matter how much space we generously give to all the rich and always historically specific mediations through which we and everybody else must know the world.

So, the further I get with the description of the radical social constructionist programme and a particular version of postmodernism, coupled to the acid tools of critical discourse in the human sciences, the more nervous I get. Like all neuroses, mine is rooted in the problem of metaphor, that is, the problem of the relation of bodies and language. For example, the force field imagery of moves in the fully textualized and coded world is the matrix for many arguments about socially negotiated reality for the postmodern subject. This world-as-code is, just for starters, a high-tech military field, a kind of automated academic battlefield, where blips of light called players disintegrate (what a metaphor!) each other in order to stay in the knowledge and power game. Technoscience and science fiction collapse into the sun of their radiant (ir)reality—war.[5] It shouldn't take decades of feminist theory to sense the enemy here. Nancy Hartsock (1983b) got all this crystal clear in her concept of abstract masculinity.

I, and others, started out wanting a strong tool for deconstructing the truth claims of hostile science by showing the radical historical specificity, and so contestability, of *every* layer of the onion of scientific and technological constructions, and we end up with a kind of epistemological electroshock therapy, which far from ushering us into the high stakes tables of the game of contesting public truths, lays us out on the table with self-induced multiple personality disorder. We wanted a way to go beyond showing bias in science (that proved too easy anyhow), and beyond separating the good scientific sheep from the bad goats of bias and misuse. It seemed promising to do this by the strongest possible constructionist argument that left no cracks for reducing the issues to bias versus objectivity, use versus misuse, science versus pseudo-science. We unmasked the doctrines of objectivity because they threatened our budding sense of collective historical subjectivity and agency and our 'embodied' accounts of the truth, and we ended up with one more excuse for not learning any post-Newtonian physics and one more reason to drop the old feminist self-help practices of repairing our own cars. They're just texts anyway, so let the boys have them back. Besides these textualized postmodern worlds are scary, and we prefer our science fiction to be a bit more utopic, maybe like *Woman on the Edge of Time* or even *Wanderground.*

Some of us tried to stay sane in these disassembled and dissembling times by holding out for a feminist version of objectivity. Here, motivated by many of the same political desires, is the other seductive end of the duplicitous objectivity problem. Humanistic Marxism was polluted at the source by its structuring ontological theory of the domination of nature in the self-construction of man and by its closely related impotence to historicize anything women did that didn't qualify for a wage. But Marxism was still a promising resource in the form of epistemological feminist mental hygiene that sought our own doctrines of objective vision. Marxist starting points offered tools to get to our versions of standpoint theories, insistent embodiment, a rich tradition of critiques of hegemony without disempowering positivisms and relativisms, and nuanced theories of mediation. Some versions of psychoanalysis aided this approach immensely, especially anglophone object relations theory, which maybe did more for US socialist-feminism for a time than anything from the pen of Marx or Engels, much less Althusser or any of the late pretenders to sonship treating the subject of ideology and science.[6]

Another approach, 'feminist empiricism', also converges with feminist uses of Marxian resources to get a theory of science which continues to insist on legitimate meanings of objectivity and which remains leery of a radical constructivism conjugated with semiology and narratology (Harding, 1986, pp. 24–6, 161–2). Feminists have to insist on a better account of the world; it is not enough to show radical historical contingency and modes of construction for everything. Here, we, as feminists, find ourselves perversely conjoined with the discourse of many practising scientists, who, when all is said and done, mostly believe they are describing and discovering things *by means of* all their constructing and arguing. Evelyn Keller has been particularly insistent on this fundamental matter, and Harding calls the goal of these approaches a 'successor science'. Feminists have stakes in a successor science project that offers a more adequate, richer, better account of a world, in order to live in it well and in critical, reflexive relation to our own as well as others' practices of domination and the unequal parts of privilege and oppression that make up all positions. In traditional philosophical categories, the issue is ethics and politics perhaps more than epistemology.

So, I think my problem and 'our' problem is how to have *simultaneously* an account of radical historical contingency for all knowledge claims and knowing subjects, a critical practice for recognizing our own 'semiotic technologies' for making meanings, *and* a no-nonsense commitment to faithful accounts of a 'real' world, one that can be partially shared and friendly to earth-wide projects of finite freedom, adequate material abundance, modest meaning in suffering, and limited happiness. Harding calls this necessary multiple desire a need for a successor science project and a postmodern insistence on irreducible difference and radical multiplicity of local knowledges. *All* components of the desire are paradoxical and dangerous, and their combination is both contradictory and necessary. Feminists don't need a doctrine of objectivity that promises transcendence, a story that loses track of its mediations just where someone might be held responsible for something, and unlimited instrumental power. We don't want a theory of innocent powers to represent the world, where language and bodies both fall into the bliss of organic symbiosis. We also don't want to theorize the world, much less act within it, in terms of Global Systems, but we do need an earth-wide network of connections, including the ability partially to translate knowledges among very different—and power-differentiated—communities. We need the power of modern critical theories of how meanings and bodies get made, not in order to deny meaning and bodies, but in order to live in meanings and bodies that have a chance for a future.

Natural, social, and human sciences have always been implicated in hopes like these. Science has been about a search for translation, convertibility, mobility of meanings, and universality—which I call reductionism, when one language (guess whose) must be enforced as the standard for all the translations and conversions. What money does in the exchange orders of capitalism, reductionism does in the powerful mental orders of global sciences: there is finally only one equation. That is the deadly fantasy that feminists and others have identified in some versions of objectivity doctrines in the service of hierarchical and positivist orderings of what can count as knowledge. That is one of the reasons the debates about objectivity matter, metaphorically and otherwise. Immortality and omnipotence are not our goals. But we could use some enforceable, reliable accounts of things not reducible to power moves and agonistic, high status games of rhetoric or to scientistic, positivist arrogance. This point applies whether we are talking about genes, social classes, elementary particles, genders, races, or texts; the point applies to the exact, natural, social, and human sciences, despite the slippery ambiguities of the words *objectivity* and *science* as we slide around the discursive terrain. In our efforts to climb the greased pole leading to a usable doctrine of objectivity, I and most other feminists in the objectivity debates have alternatively, or even simultaneously, held on to both ends of the dichotomy, which Harding describes in terms of successor science projects versus postmodernist accounts of difference and I have sketched as radical constructivism versus feminist critical empiricism. It is, of course, hard to climb when you are holding on to both ends of a pole, simultaneously or alternately. It is, therefore, time to switch metaphors.

THE PERSISTENCE OF VISION[7]

I would like to proceed by placing metaphorical reliance on a much maligned sensory system in feminist discourse: vision. Vision can be good for avoiding binary oppositions. I would like to insist on the embodied nature of all vision, and so reclaim the sensory system that has been used to signify a leap out of the marked body and into a conquering gaze from nowhere. This is the gaze that mythically inscribes all the marked bodies, that makes the unmarked category claim the power to see and not be seen, to represent while escaping representation. This gaze signifies the unmarked positions of Man and White, one of the many nasty tones of the world *objectivity* to feminist ears in scientific and technological, late industrial, militarized, racist and male dominant societies, that is, here, in the belly of the monster, in the United States in the late 1980s. I would like a doctrine of embodied objectivity that accommodates paradoxical and critical feminist science projects: feminist objectivity means quite simply *situated knowledges*.

The eyes have been used to signify a perverse capacity—honed to perfection in the history of science tied to militarism, capitalism, colonialism, and male supremacy—to distance the knowing subject from everybody and everything in the interests of unfettered power. The instruments of visualization in multinationalist, postmodernist culture have compounded these meanings of dis-embodiment. The visualizing technologies are without apparent limit; the eye of any ordinary primate like us can be endlessly enhanced by sonography systems, magnetic resonance imaging, artificial intelligence-linked graphic manipulation systems, scanning electron microscopes, computer-aided tomography scanners, colour enhancement techniques, satellite surveillance systems, home and office VDTs, cameras for every purpose from filming the mucous membrane lining the gut cavity of a marine worm living in the vent gases on a fault between continental plates to mapping a planetary hemisphere elsewhere in the solar system. Vision in this technological feast becomes unregulated gluttony; all perspective gives way to infinitely mobile vision, which no longer seems just mythically about the god-trick of seeing everything from nowhere, but to have put the myth into ordinary practice.

And like the god-trick, this eye fucks the world to make techno-monsters. Zoe Sofoulis (1988) calls this the cannibal-eye of masculinist extra-terrestrial projects for excremental second birthing.

A tribute to this ideology of direct, devouring, generative, and unrestricted vision, whose technological mediations are simultaneously celebrated and presented as utterly transparent, the volume celebrating the 100th anniversary of the National Geographic Society closes its survey of the magazine's quest literature, effected through its amazing photography, with two juxtaposed chapters. The first is on 'Space', introduced by the epigraph, 'The choice is the universe—or nothing' (Bryan, 1987, p. 352). Indeed. This chapter recounts the exploits of the space race and displays the colour-enhanced 'snapshots' of the outer planets reassembled from digitalized signals transmitted across vast space to let the viewer 'experience' the moment of discovery in immediate vision of the 'object'.[8] These fabulous objects come to us simultaneously as indubitable recordings of what is simply there and as heroic feats of techno-scientific production. The next chapter is the twin of outer space: 'Inner Space', introduced by the epigraph, 'The stuff of stars has come alive' (Bryan, 1987, p. 454). Here, the reader is brought into the realm of the infinitesimal, objectified by means of radiation outside the wave lengths that 'normally' are perceived by hominid primates, i.e., the beams of lasers and scanning electron microscopes, whose signals are processed into the wonderful full-colour snapshots of defending cells and invading viruses.

But of course that view of infinite vision is an illusion, a god-trick. I would like to suggest how our insisting metaphorically on the particularity and embodiment of all vision (though not necessarily organic embodiment and including technological mediation), and not giving in to the tempting myths of vision as a route to disembodiment and second-birthing, allows us to construct a usable, but not an innocent, doctrine of objectivity. I want a feminist writing of the body that metaphorically emphasizes vision again, because we need to reclaim that sense to find our way through all the visualizing tricks and powers of modern sciences and technologies that have transformed the objectivity debates. We need to learn in our bodies, endowed with primate colour and stereoscopic vision, how to attach the objective to our theoretical and political scanners in order to name where we are and are not, in dimensions of mental and physical space we hardly know how to name. So, not so perversely, objectivity turns out to be about particular and specific embodiment, and definitely not about the false vision promising transcendence of all limits and responsibility. The moral is simple: only partial perspective promises objective vision. This is an objective vision that initiates, rather than closes off, the problem of responsibility for the generativity of all visual practices. Partial perspective can be held accountable for both its promising and its destructive monsters. All Western cultural narratives about objectivity are allegories of the ideologies of the relations of what we call mind and body, of distance and responsibility, embedded in the science question in feminism. Feminist objectivity is about limited location and situated knowledge, not about transcendence and splitting of subject and object. In this way we might become answerable for what we learn how to see.

These are lessons which I learned in part walking with my dogs and wondering how the world looks without a fovea and very few retinal cells for colour vision, but with a huge neural processing and sensory area for smells. It is a lesson available from photographs of how the world looks to the compound eyes of an insect, or even from the camera eye of a spy satellite or the digitally transmitted signals of space probe-perceived differences 'near' Jupiter that have been transformed into coffee table colour photographs. The 'eyes' made available in modem technological sciences shatter any idea of passive vision; these prosthetic devices show us that all eyes, including our own organic ones, are active perceptual systems, building in translations and specific *ways* of seeing, that is, ways of life. There is no unmediated photograph or passive camera obscura in scientific accounts of bodies and machines; there are only highly specific visual possibilities, each with a wonderfully detailed, active, partial way of organizing worlds. All these pictures of the world should not be allegories of infinite mobility and interchangeability, but of elaborate specificity and difference and the loving care people might take to learn how to see faithfully from another's point of view, even when the other is our own machine. That's not alienating distance; that's a *possible* allegory for feminist versions of objectivity. Understanding how these visual systems work, technically, socially, and psychically ought to be a way of embodying feminist objectivity.

Many currents in feminism attempt to theorize grounds for trusting especially the vantage points of the subjugated; there is good reason to believe vision is better from below the brilliant space platforms of the powerful (Hartsock, 1983a; Sandoval, n.d.; Harding, 1986; Anzaldúa, 1987). Linked to this suspicion is an argument for situated and embodied knowledges and against various forms of unlocatable, and so irresponsible, knowledge claims. Irresponsible means unable to be called into account. There is a premium on establishing the capacity to see from the peripheries and the depths. But here lies a serious danger of romaticizing and/or appropriating the vision of the less powerful while claiming to see from their positions. To see from below is neither easily learned nor unproblematic, even if 'we' 'naturally' inhabit the great underground terrain of subjugated knowledges. The positionings of the subjugated are not exempt from critical reexamination, decoding, deconstruction, and interpretation; that is, from both semiological and hermeneutic modes of critical enquiry. The standpoints of the subjugated are not 'innocent' positions. On the contrary, they are preferred because in principle they are least likely to allow denial of the critical and interpretative core of all knowledge. They are savvy to modes of denial through repression, forgetting, and disappearing acts—ways of being nowhere while claiming to see comprehensively. The subjugated have a decent chance to be on to the god-trick and all its dazzling—and, therefore, blinding—illuminations. 'Subjugated' standpoints are preferred because they seem to promise more adequate, sustained, objective, transforming accounts of the world. But *how* to see from below is a problem requiring at least as much skill with bodies and language, with the mediations of vision, as the 'highest' techno-scientific visualizations.

Such preferred positioning is as hostile to various forms of relativism as to the most explicitly totalizing versions of claims to scientific authority. But the alternative to relativism is not totalization and single vision, which is always finally the unmarked category whose power depends on systematic narrowing and obscuring. The alternative to relativism is partial, locatable, critical knowledges sustaining the possibility of webs of connections called solidarity in politics and shared conversations in epistemology. Relativism is a way of being nowhere while claiming to be everywhere equally. The 'equality' of positioning is a denial of responsibility and critical enquiry. Relativism is the perfect mirror twin of totalization in the ideologies of objectivity;

both deny the stakes in location, embodiment, and partial perspective; both make it impossible to see well. Relativism and totalization are both 'god-tricks' promising vision from everywhere and nowhere equally and fully, common myths in rhetorics surrounding Science. But it is precisely in the politics and epistemology of partial perspectives that the possibility of sustained, rational, objective enquiry rests.

So, with many other feminists, I want to argue for a doctrine and practice of objectivity that privileges contestation, deconstruction, passionate construction, webbed connections, and hope for transformation of systems of knowledge and ways of seeing. But not just any partial perspective will do; we must be hostile to easy relativisms and holisms built out of summing and subsuming parts. 'Passionate detachment' (Kuhn, 1982) requires more than acknowledged and self-critical partiality. We are also bound to seek perspective from those points of view, which can never be known in advance, which promise something quite extraordinary, that is, knowledge potent for constructing worlds less organized by axes of domination. In such a viewpoint, the unmarked category would *really* disappear—quite a difference from simply repeating a disappearing act. The imaginary and the rational—the visionary and objective vision—hover close together. I think Harding's plea for a successor science and for postmodern sensibilities must be read to argue that this close touch of the fantastic element of hope for transformative knowledge and the severe check and stimulus of sustained critical enquiry are jointly the ground of any believable claim to objectivity or rationality not riddled with breath-taking denials and repressions. It is even possible to read the record of scientific revolutions in terms of this feminist doctrine of rationality and objectivity. Science has been utopian and visionary from the start; that is one reason 'we' need it.

A commitment to mobile positioning and to passionate detachment is dependent on the impossibility of innocent 'identity' politics and epistemologies as strategies for seeing from the standpoints of the subjugated in order to see well. One cannot 'be' either a cell or molecule—or a woman, colonized person, labourer, and so on—if one intends to see and see from these positions critically. 'Being' is much more problematic and contingent. Also, one cannot relocate in any possible vantage point without being accountable for that movement. Vision is *always* a question of the power to see—and perhaps of the violence implicit in our visualizing practices. With whose blood were my eyes crafted? These points also apply to testimony from the position of 'oneself'. We are not immediately present to ourselves. Self-knowledge requires a semiotic-material technology linking meanings and bodies. Self-identity is a bad visual system. Fusion is a bad strategy of positioning. The boys in the human sciences have called this doubt about self-presence the 'death of the subject', that single ordering point of will and consciousness. That judgement seems bizarre to me. I prefer to call this generative doubt the opening of non-isomorphic subjects, agents, and territories of stories unimaginable from the vantage point of the cyclopian, self-satiated eye of the master subject. The Western eye has fundamentally been a wandering eye, a travelling lens. These peregrinations have often been violent and insistent on mirrors for a conquering self—but not always. Western feminists also *inherit* some skill in learning to participate in revisualizing worlds turned upside down in earth-transforming challenges to the views of the masters. All is not to be done from scratch.

The split and contradictory self is the one who can interrogate positionings and be accountable, the one who can construct and join rational conversations and fantastic imaginings that change history.[9] Splitting, not being, is the privileged image for feminist epistemologies of scientific knowledge. 'Splitting' in this context should be about heterogeneous multiplicities that are simultaneously necessary and incapable of being squashed into isomorphic slots or cumulative lists. This geometry pertains within and among subjects. The topography of subjectivity is multidimensional; so, therefore, is vision. The knowing self is partial in all its guises, never finished, whole, simply there and original; it is always constructed and stitched together imperfectly, and *therefore* able to join with another, to see together without claiming to be another. Here is the promise of objectivity: a scientific knower seeks the subject position not of identity, but of objectivity; that is, partial connection. There is no way to 'be' simultaneously in all, or wholly in any, of the privileged (subjugated) positions structured by gender, race, nation, and class. And that is a short list of critical positions. The search for such a 'full' and total position is the search for the fetishized perfect subject of oppositional history, sometimes appearing in feminist theory as the essentialized Third World Woman (Mohanty, 1984). Subjugation is not grounds for an ontology; it might be a visual clue. Vision requires instruments of vision; an optics is a politics of positioning. Instruments of vision mediate standpoints; there is no immediate vision from the standpoints of the subjugated. Identity, including self-identity, does not produce science; critical positioning does, that is, objectivity. Only those occupying the positions of the dominators are self-identical, unmarked, disembodied, unmediated, transcendent, born again. It is unfortunately possible for the subjugated to lust for and even scramble into that subject position—and then disappear from view. Knowledge from the point of view of the unmarked is truly fantastic, distorted, and so irrational. The only position from which objectivity could not possibly be practised and honoured is the standpoint of the master, the Man, the One God, whose Eye produces, appropriates, and orders all difference. No one ever accused the God of monotheism of objectivity, only of indifference. The god-trick is self-identical, and we have mistaken that for creativity and knowledge, omniscience even.

Positioning is, therefore, the key practice grounding knowledge organized around the imagery of vision, as so much Western scientific and philosophic discourse is organized. Positioning implies responsibility for our enabling practices. It follows that politics and ethics ground struggles for the contests over what may count as rational knowledge. That is, admitted or not, politics and ethics ground struggles over knowledge projects in the exact, natural, social, and human sciences. Otherwise, rationality is simply impossible, an optical illusion projected from nowhere comprehensively. Histories of science may be powerfully told as histories of the technologies. These technologies are ways of life, social orders, practices of visualization. Technologies are skilled practices. How to see? Where to see from? What limits to vision? What to see for? Whom to see with? Who gets to have more than one point of view? Who gets blinkered? Who wears blinkers? Who interprets the visual field? What other sensory powers do we wish to cultivate besides vision? Moral and political discourse should be the paradigm of rational discourse in the imagery and technologies of vision. Sandra Harding's claim, or observation, that movements of social revolution have most contributed to improvements in science might be read as a claim about the knowledge consequences of new technologies of positioning. But I wish Harding had spent more time remembering that social and scientific revolutions have not always been liberatory, even if they have always been visionary. Perhaps this point could be captured in another phrase: the science question in the military. Struggles over what will count as rational accounts of the world are struggles over *how* to see. The terms of vision: the science question in colonialism; the science question in exterminism (Sofoulis, 1988); the science question in feminism.

The issue in politically engaged attacks on various empiricisms, reductionisms, or other versions of scientific authority should not be relativism, but location. A dichotomous chart expressing this point might look like this:

universal rationality	ethnophilosophies
common language	heteroglossia
new Organon	deconstruction
unified field theory	oppositional positioning
world system	local knowledges
master theory	webbed accounts

But a dichotomous chart misrepresents in a critical way the positions of embodied objectivity which I am trying to sketch. The primary distortion is the illusion of symmetry in the chart's dichotomy, making any position appear, first, simply alternative and, second, mutually exclusive. A map of tensions and resonances between the fixed ends of a charged dichotomy better represents the potent politics and epistemologies of embodied, therefore accountable, objectivity. For example, local knowledges have also to be in tension with the productive structurings that force unequal translations and exchanges—material and semiotic—within the webs of knowledge and power. Webs *can* have the property of systematicity, even of centrally structured global systems with deep filaments and tenacious tendrils into time, space and consciousness, the dimensions of world history. Feminist accountability requires a knowledge tuned to resonance, not to dichotomy. Gender is a field of structured and structuring difference, where the tones of extreme localization, of the intimately personal and individualized body, vibrate in the same field with global high tension emissions. Feminist embodiment, then, is not about fixed location in a reified body, female or otherwise, but about nodes in fields, inflections in orientations, and responsibility for difference in material-semiotic fields of meaning. Embodiment is significant prosthesis; objectivity cannot be about fixed vision when what counts as an object is precisely what world history turns out to be about.

How should one be positioned in order to see in this situation of tensions, resonances, transformations, resistances, and complicities? Here, primate vision is not immediately a very powerful metaphor or technology for feminist political-epistemological clarification, since it seems to present to consciousness already processed and objectified fields; things seem already fixed and distanced. But the visual metaphor allows one to go beyond fixed appearances, which are only the end products. The metaphor invites us to investigate the varied apparatuses of visual production, including the prosthetic technologies interfaced with our biological eyes and brains. And here we find highly particular machineries for processing regions of the electro-magnetic spectrum into our pictures of the world. It is in the intricacies of these visualization technologies in which we are embedded that we will find metaphors and means for understanding and intervening in the patterns of objectification in the world, mat is, the patterns of reality for which we must be accountable. In these metaphors, we find means for appreciating simultaneously *both* the concrete, 'real' aspect and the aspect of semiosis and production in what we call scientific knowledge.

I am arguing for politics and epistemologies of location, positioning, and situating, where partiality and not universality is the condition of being heard to make rational knowledge claims. These are claims on people's Uves; the view from a body, always a complex, contradictory, structuring and structured body, versus the view from above, from nowhere, from simplicity. Only the god-trick is forbidden. Here is a criterion for deciding the science question in militarism, that dream science/technology of perfect language, perfect communication, final order.

Feminism loves another science: the sciences and politics of interpretation, translation, stuttering, and the partly understood. Feminism is about the sciences of the multiple subject with (at least) double vision. Feminism is about a critical vision consequent upon a critical positioning in inhomogeneous gendered social space.[10] Translation is always interpretative, critical, and partial. Here is a ground for conversation, rationality, and objectivity—which is power-sensitive, not pluralist, 'conversation'. It is not even the mythic cartoons of physics and mathematics—incorrectly caricatured in anti-science ideology as exact, hyper-simple knowledges—that have come to represent the hostile other to feminist paradigmatic models of scientific knowledge, but the dreams of the perfectly known in high-technology, permanently militarized scientific productions and positionings, the god-trick of a Star Wars paradigm of rational knowledge. So location is about vulnerability; location resists the politics of closure, finality, or, to borrow from Althusser, feminist objectivity resists 'simplification in the last instance'. That is because feminist embodiment resists fixation and is insatiably curious about the webs of differential positioning. There is no single feminist standpoint because our maps require too many dimensions for that metaphor to ground our visions. But the feminist standpoint theorists' goal of an epistemology and politics of engaged, accountable positioning remains eminently potent. The goal is better accounts of the world, that is, 'science'.

Above all, rational knowledge does not pretend to disengagement: to be from everywhere and so nowhere, to be free from interpretation, from being represented, to be fully self-contained or fully formalizable. Rational knowledge is a process of ongoing critical interpretation among 'fields' of interpreters and decoders. Rational knowledge is power-sensitive conversation (King, 1987a):

knowledge:community::knowledge:power
hermeneutics:semiology::critical interpretation:codes.

Decoding and transcoding plus translation and criticism; all are necessary. So science becomes the paradigmatic model not of closure, but of that which is contestable and contested. Science becomes the myth not of what escapes human agency and responsibility in a realm above the fray, but rather of accountability and responsibility for translations and solidarities linking the cacophonous visions and visionary voices that characterize the knowledges of the subjugated. A splitting of senses, a confusion of voice and sight, rather than clear and distinct ideas, becomes the metaphor for the ground of the rational. We seek not the knowledges ruled by phallogocentrism (nostalgia for the presence of the one true Word) and disembodied vision, but those ruled by partial sight and limited voice. We do not seek partiality for its own sake, but for the sake of the connections and unexpected openings situated knowledges make possible. The only way to find a larger vision is to be somewhere in particular. The science question in feminism is about objectivity as positioned rationality. Its images are not the products of escape and transcendence of limits, i.e., the view from above, but the joining of partial views and halting voices into a collective subject position that promises a vision of the means of ongoing finite embodiment, of living within limits and contradictions, i.e., of views from somewhere.

OBJECTS AS ACTORS: THE APPARATUS OF BODILY PRODUCTION

Throughout this reflection on 'objectivity', I have refused to resolve the ambiguities built into referring to science without differentiating its extraordinary range of contexts. Through the insistent ambiguity, I have foregrounded a field of commonalities binding exact, physical, natural, social, political, biological, and human sciences; and I have tied this whole heterogeneous field of academically (and industrially, for example, in publishing, the weapons trade, and pharmaceuticals) institutionalized knowledge production to a meaning of science that insists on its potency in ideological struggles. But, partly in order to give play to both the specificities and the highly permeable boundaries of meanings in discourse on science, I would like to suggest a resolution to one ambiguity. Throughout the field of meanings constituting science, one of the commonalities concerns the status of any object of knowledge and of related claims about the faithfulness of our accounts to a 'real world', no matter how mediated for us and no matter how complex and contradictory these worlds may be. Feminists, and others who have been most active as critics of the sciences and their claims or associated ideologies, have shied away from doctrines of scientific objectivity in part because of the suspicion that an 'object' of knowledge is a passive and inert thing. Accounts of such objects can seem to be either appropriations of a fixed and determined world reduced to resource for the instrumentalist projects of destructive Western societies, or they can be seen as masks for interests, usually dominating interests.

For example, 'sex' as an object, of biological knowledge appears regularly in the guise of biological determinism, threatening the fragile space for social constructionism and critical theory, with their attendant possibilities for active and transformative intervention, called into being by feminist concepts of gender as socially, historically, and semiotically positioned difference. And yet, to lose authoritative biological accounts of sex, which set up productive tensions with its binary pair, gender, seems to be to lose too much; it seems to be to lose not just analytic power within a particular Western tradition, but the body itself as anything but a blank page for social inscriptions, including those of biological discourse. The same problem of loss attends a radical 'reduction' of the objects of physics or of any other sciences to the ephemera of discursive production and social construction.[11]

But the difficulty and loss are not necessary. They derive partly from the analytical tradition, deeply indebted to Aristotle and to the transformative history of 'White Capitalist Patriarchy' (how may we name this scandalous Thing?) that turns everything into a resource for appropriation, in which an object of knowledge is finally itself only matter for the seminal power, the act, of the knower. Here, the object both guarantees and refreshes the power of the knower, but any status as *agent* in the productions of knowledge must be denied the object. It—the world—must, in short, be objectified as thing, not as an agent; it must be matter for the self-formation of the only social being in the productions of knowledge, the human knower. Zoe Sofoulis (1988) identified the structure of this mode of knowing in technoscience as 'resourcing'—the second-birthing of Man through the homogenizing of all the world's body into resource for his perverse projects. Nature is only the raw material of culture, appropriated, preserved, enslaved, exalted, or otherwise made flexible for disposal by culture in the logic of capitalist colonialism. Similarly, sex is only the matter to the act of gender; the productionist logic seems inescapable in traditions of Western binarisms. This analytical and historical narrative logic accounts for my nervousness about the sex/gender distinction in the recent history of feminist theory. Sex is 'resourced' for its re-presentation as gender, which 'we' can control. It has seemed all but impossible to avoid the trap of an appropriationist logic of domination built into the nature/culture binarism and its generative lineage, including the sex/gender distinction.

It seems clear that feminist accounts of objectivity and embodiment—that is, of a world—require a deceptively simple manoeuvre within inherited Western analytical traditions, a manoeuvre begun in dialectics, but stopping short of the needed revisions. Situated knowledges require that the object of knowledge be pictured as an actor and agent, not a screen or a ground or a resource, never finally as slave to the master that closes off the dialectic in his unique agency and authorship of 'objective' knowledge. The point is paradigmatically clear in critical approaches to the social and human sciences, where the agency of people studied itself transforms the entire project of producing social theory. Indeed, coming to terms with the agency of the 'objects' studied is the only way to avoid gross error and false knowledge of many kinds in these sciences. But the same point must apply to the other knowledge projects called sciences. A corollary of the insistence that ethics and politics covertly or overtly provide the bases for objectivity in the sciences as a heterogeneous whole, and not just in the social sciences, is granting the status of agent/actor to the 'objects' of the world. Actors come in many and wonderful forms. Accounts of a 'real' world do not, then, depend on a logic of 'discovery', but on a power-charged social relation of 'conversation'. The world neither speaks itself nor disappears in favour of a master decoder. The codes of the world are not still, waiting only to be read. The world is not raw material for humanization; the thorough attacks on humanism, another branch of 'death of the subject' discourse, have made this point quite clear. In some critical sense that is crudely hinted at by the clumsy category of the social or of agency, the world encountered in knowledge projects is an active entity. In so far as a scientific account has been able to engage this dimension of the world as object of knowledge, faithful knowledge can be imagined and can make claims on us. But no particular doctrine of representation or decoding or discovery guarantees anything. The approach I am recommending is not a version of 'realism', which has proved a rather poor way of engaging with the world's active agency.

My simple, perhaps simple-minded, manoeuvre is obviously not new in Western philosophy, but it has a special feminist edge to it in relation to the science question in feminism and to the linked questions of gender as situated difference and of female embodiment. Ecofeminists have perhaps been most insistent on some version of the world as active subject, not as resource to be mapped and appropriated in bourgeois, Marxist, or masculinist projects. Acknowledging the agency of the world in knowledge makes room for some unsettling possibilities, including a sense of the world's independent sense of humour. Such a sense of humour is not comfortable for humanists and others committed to the world as resource. Richly evocative figures exist for feminist visualizations of the world as witty agent. We need not lapse into an appeal to a primal mother resisting becoming resource. The Coyote or Trickster, embodied in American Southwest Indian accounts, suggests our situation when we give up mastery but keep searching for fidelity, knowing all the while we will be hoodwinked. I think these are useful myths for scientists who might be our allies. Feminist objectivity makes room for surprises and ironies at the heart of all knowledge production; we are not in charge of the world. We just live here and try to strike up non-innocent conversations by means of our prosthetic devices, including our visualization technologies. No wonder science fiction has been such a rich writing practice in recent feminist theory. I like to see feminist theory as a reinvented coyote discourse obligated to its enabling sources in many kinds of heterogeneous accounts of the world.

Another rich feminist practice in science in the last couple of decades illustrates particularly well the 'activation' of the previously passive categories of objects of knowledge. The activation permanently problematizes binary distinctions like sex and gender, without however eliminating their strategic utility. I refer to the reconstructions in primatology, especially but not only women's practice as primatologists, evolutionary biologists, and behavioural ecologists, of what may count as sex, especially as female sex, in scientific accounts (Haraway, 1989b). The *body,* the object of biological discourse, itself becomes a most engaging being. Claims of biological determinism can never be the same again. When female 'sex' has been so thoroughly re-theorized and revisualized that it emerges as practically indistinguishable from 'mind', something basic has happened to the categories of biology. The biological female peopling current biological behavioural accounts has almost no passive properties left. She is structuring and active in every respect; the 'body' is an agent, not a resource. Difference is theorized *biologically* as situational, not intrinsic, at every level from gene to foraging pattern, thereby fundamentally changing the biological politics of the body. The relations between sex and gender have to be categorically reworked within these frames of knowledge. I would like to suggest this trend in explanatory strategies in biology as an allegory for interventions faithful to projects of feminist objectivity. The point is not that these new pictures of the biological female are simply true or not open to contestation and conversation. Quite the opposite. But these pictures foreground knowledge as situated conversation at every level of its articulation. The boundary between animal and human is one of the stakes in this allegory, as well as that between machine and organism.

So I will close with a final category useful to a feminist theory of situated knowledges: the apparatus of bodily production. In her analysis of the production of the poem as an object of literary value, Katie King offers tools that clarify matters in the objectivity debates among feminists. King suggests the term 'apparatus of literary production' to highlight the emergence of what is embodied as literature at the intersection of art, business, and technology. The apparatus of literary production is a matrix from which 'literature' is born. Focusing on the potent object of value called the 'poem', King applies her analytic frame to the relation of women and writing technologies (King, 1987b). I would like to adapt her work to understanding the generation—the actual production and reproduction—of bodies and other objects of value in scientific knowledge projects. At first glance, there is a limitation to using King's scheme inherent in the 'facticity' of biological discourse that is absent from literary discourse and its knowledge claims. Are biological bodies 'produced' or 'generated' in the same strong sense as poems? From the early stirrings of Romanticism in the late eighteenth century, many poets and biologists have believed that poetry and organisms are siblings. *Frankenstein* may be read as a meditation on this proposition. I continue to believe in this potent proposition, but in a postmodern and not a Romantic manner of belief. I wish to translate the ideological dimensions of 'facticity' and 'the organic' into a cumbersome entity called a 'material-semiotic actor'. This unwieldy term is intended to highlight the object of knowledge as an active, meaning-generating axis of the apparatus of bodily production, without *ever* implying immediate presence of such objects or, what is the same thing, their final or unique determination of what can count as objective knowledge at a particular historical juncture. Like King's objects called 'poems', which are sites of literary production where language also is an actor independent of intentions and authors, bodies as objects of knowledge are material-semiotic generative nodes. Their *boundaries* materialize in social interaction. Boundaries are drawn by mapping practices; 'objects' do not pre-exist as such. Objects are boundary projects. But boundaries shift from within; boundaries are very tricky. What boundaries provisionally contain remains generative, productive of meanings and bodies. Siting (sighting) boundaries is a risky practice.

Objectivity is not about dis-engagement, but about mutual *and* usually unequal structuring, about taking risks in a world where 'we' are permanently mortal, that is, not in 'final' control. We have, finally, no clear and distinct ideas. The various contending biological bodies emerge at the intersection of biological research and writing, medical and other business practices, and technology, such as the visualization technologies enlisted as metaphors in this chapter. But also invited into that node of intersection is the analogue to the lively languages that actively intertwine in the production of literary value: the coyote and protean embodiments of a world as witty agent and actor. Perhaps the world resists being reduced to mere resource because it is—not mother/matter/mutter—but coyote, a figure for the always problematic, always potent tie of meaning and bodies. Feminist embodiment, feminist hopes for partiality, objectivity and situated knowledges, turn on conversations and codes at this potent node in fields of possible bodies and meanings. Here is where science, science fantasy, and science fiction converge in the objectivity question in feminism. Perhaps our hopes for accountability, for politics, for ecofeminism, turn on revisioning the world as coding trickster with whom we must learn to converse.

NOTES

1. This chapter originated as a commentary on Harding (1986), at the Western Division meetings of the American Philosophical Association, San Francisco, March 1987. Support during the writing of this paper was generously provided by the Alpha Fund of the Institute for Advanced Study, Princeton, New Jersey. Thanks especially to Joan Scott, Rayna Rapp, Judy Newton, Judy Butler, Lila Abu-Lughod, and Dorinne Kondo.
2. For example, see Karin Knorr-Cetina and Michael Mulkay (1983); Bijker *et al.* (1987); and especially, Latour (1984, 1988). Borrowing from Michael Tournier's *Vendredi* (1967), Latour's brilliant and maddening aphoristic polemic against all forms of reductionism, makes the essential point for feminists: "Méfiez-vous de la pureté, c'est le vitriol de l'ame" (Latour, 1984, p. 171). Latour is not otherwise a notable feminist theorist, but he might be made into one by readings as perverse as those he makes of the laboratory, that great machine for making significant mistakes faster than anyone else can, and so gaining world-changing power. The laboratory for Latour is the railroad industry of epistemology, where facts can only be made to run on the tracks laid down from the laboratory out. Those who control the railroads control the surroundings territory. How could we have forgotten? But now it's not so much the bankrupt railroads we need as the satellite network. Facts run on light beams these days.
3. For an elegant and very helpful elucidation of a non-cartoon version of this argument, see White (1987), I still want more; and unfulfilled desire can be a powerful seed for changing the stories.
4. In her analysis exploring the fault line between modernism and postmodernism in ethnography and anthropology — in which the high stakes are the authorization or prohibition to craft *comparative* knowledge across "cultures", from some epistemologically grounded vantage point *either* inside, outside, or in dialogical relation with any unit of analysis — Marilyn Strathern (1987a) made the crucial observation that it is not the

written ethnography that is parallel to the work of art as object-of-knowledge, but the *culture*. The Romantic and modernist natural-technical objects of knowledge, in science and in order cultural practice, stand on one side of this divide. The postmodernist formation stands on the other side, with its "anti-aesthetic" of permanently split, problematized, always receding and deferred "objects" of knowledge and practice, including signs, organisms, systems, selves, and cultures. "Objectivity" in a postmodern frame cannot be about unproblematic objects; it must be about specific prosthesis and translation. Objectivity, which at root has been about crafting *comparative* knowledge (how to name things to be stable and to be like each other), becomes a question of the politics of redrawing of boundaries in order to have non-innocent conversations and connections. What is at stake in the debates about modernism and postmodernism is the pattern of relationships between and within bodies and language.

5. Zoe Sofoulis (1988) has produced a dazzlingly (she will forgive me the metaphor) theoretical treatment of technosience, the psychoanalysis of science fiction culture, and the metaphorics of extra-terrestrialism, including a wonderful focus on the ideologies and philosophies of light, illumination, and discovery in Western mythics of science and technology. My essay was revised in dialogue with Sofoulis's arguments and metaphors in her PhD dissertation.
6. Crucial to this discussion are Sandra Harding (1986), Keller (1985), Hartsock (1983a, 1983b), Flax (1983, 1987), Keller and Grontkowski (1983), H. Rose, (1986) Haraway (1991), Petchesky (1987).
7. John Varley's science fiction short story, "The Persistence of Vision", is part of the inspiration for this section. In the story, Varley constructs a utopian community designed and built by the deaf-blind. He then explores these people's technologies and other mediations of communication and their relations to sighted children and visitors (Varley, 1978). In the story, "Blue Champagne", Varley (1986), transmutes the theme to interrogate the politics of intimacy and technology for a paraplegic young woman whose prosthetic device, the golden gypsy, allows her full mobility. But since the infinitely costly device is owned by an intergalactic communications and entertainment empire for which she works as a media star making "feelies", she may keep her technological, intimate, enabling, other self only in exchange for her complicity in the commodification of all experience. What are her limits to the reinvention of experience for sale? Is the personal political under the sign of simulation? One way to read Varley's repeated investigations of finally always limited embodiments, differently abled beings, prosthetic technologies, and cyborgian encounters with their finitude, despite their extraordinary transcedence of "organic" orders is to find an allegory for the personal and political in the historical mythic time of the late twentieth century, the era of techno-biopolitics. Prosthesis is semiosis, the making of meanings and bodies, not for transcendence, but for power-charged communication.
8. I owe my understanding of the experience of these photographs to Jim Clifford, University of California at Santa Cruz, who identified their "land ho!" effect on the reader.
9. Joan Scott reminded me that Teresa de Lauretis (1986a, pp. 14–15) put it like this: Differences among women may be better understood as differences within women . . . But once understood in their constitutive power — once it is understood, that is, that these differences not only constitute each woman's consciousness and subjective limits but all together define the *female subject of feminism* in its very specificity, is inherent and at least for now irreconcilable contradiction — these differences, then, cannot be again collapsed into a fixed identity, a sameness of all women as Woman, or a representation of Feminism as a coherent and available image.
10. Harding (1986, p. 18) suggested that gender has three dimensions, each historically specific: gender symbolism, the social-sexual division of labor, and processes of constructing individual gendered identity. I would enlarge her point to note that there is no reason to expect the three dimensions to co-vary or co-determine each other, at least not directly. That is, extremely steep gradients between contrasting terms in gender symbolism may very well not correlate with sharp social-sexual divisions of labour or social power, but may be closely related to sharp racial stratification or something else. Similarly, the processes of gendered subject formation may not be directly illuminated by knowledge of the sexual division of labour or the gender symbolism in the particular historical situation under examination. On the other hand, we should expect mediated relations among the dimensions. The mediations might move through quite different social axes of organization of both symbols, practice, and identity, such as race. And vice versa. I would suggest also that science, as well as gender or race, might usefully be broken up into such a multi-part scheme of symbolism, social practice, and subject position. More than three dimensions

suggest themselves when the parallels are drawn. The different dimensions of, for example, gender, race and science might mediate relations among dimensions on a parallel chart. That is, racial divisions of labour might mediate the patterns of connection between symbolic connections and formation of individual subject positions on the science or gender chart. Or formations of gendered or racial subjectivity might mediate the relations between scientific social division of labour and scientific symbolic patterns.

The chart below begins an analysis by parallel dissections. In the chart (and in reality?), both gender and science are analytically asymmetrical; i.e., each term contains and obscures a structuring hierachicalized binarism, sex/gender and nature/science. Each binarism orders the silent term by a logic of appropriation, as resource to product, nature to culture, potential to actual. Both poles of the binarism are contructed and structure each other dialectically. Within each voiced or explicit term, further asymmetrical splittings can be excavated, as from gender, masculine to feminine, and from science, hard sciences to soft sciences. This is a point about remembering how a particular analytical tool works, willy nilly, intended or not. The chart reflects common ideological aspects of discourse on science and gender and may help as an analytical tool to crack open mystified units like Science or Woman.

GENDER	SCIENCE
symbolic system	symbolic system
social division of labor (by sex, by race, etc.)	social division of labor (e.g. by craft, industrial, or post-industrial logics)
individual identity/ subject position (desiring/desired; autonomous/relational)	individual identity/ subject position (knower/known; scientist/ other)
material culture (gender paraphernalia and daily gender technological, the narrow tracks on which sexual difference runs)	material culture (laboratories the narrow tracks on which facts run)
dialectic of construction and discovery	dialectic of construction and discovery

11. Evelyn Keller (1987) insists on the important possibilities opened up by the construction of the intersection of the distinction between sex and gender, on the one hand, and nature and science, on the other. She also insists on the need to hold to some non-discursive grounding in "sex" and "nature", perhaps what I am calling the "body" and "world".

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CHAPTER 28

Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter

Karen Barad

> *Where did we ever get the strange idea that nature—as opposed to culture—is ahistorical and timeless? We are far too impressed by our own cleverness and self-consciousness. . . . We need to stop telling ourselves the same old anthropocentric bedtime stories.*
>
> —Steve Shaviro 1997

Language has been granted too much power. The linguistic turn, the semiotic turn, the interpretative turn, the cultural turn: it seems that at every turn lately every "thing"—even materiality—is turned into a matter of language or some other form of cultural representation. The ubiquitous puns on "matter" do not, alas, mark a rethinking of the key concepts (materiality and signification) and the relationship between them. Rather, it seems to be symptomatic of the extent to which matters of "fact" (so to speak) have been replaced with matters of signification (no scare quotes here). Language matters. Discourse matters. Culture matters. There is an important sense in which the only thing that does not seem to matter anymore is matter.

What compels the belief that we have a direct access to cultural representations and their content that we lack toward the things represented? How did language come to be more trustworthy than matter? Why are language and culture granted their own agency and historicity while matter is figured as passive and immutable, or at best inherits a potential for change derivatively from language and culture? How does one even go about inquiring after the material conditions that have led us to such a brute reversal of naturalist beliefs when materiality itself is always already figured within a linguistic domain as its condition of possibility?

It is hard to deny that the power of language has been substantial. One might argue too substantial, or perhaps more to the point, too substantializing. Neither an exaggerated faith in the power of language nor the expressed concern that language is being granted too much power is a novel apprehension specifically attached to the early twenty-first century. For example, during the nineteenth century Nietzsche warned against the mistaken tendency to take grammar too seriously: allowing linguistic structure to shape or determine our understanding of the world, believing that the subject and predicate structure of language reflects a prior ontological reality of substance and attribute. The belief that grammatical categories reflect the underlying structure of the world is a continuing seductive habit of mind worth questioning. Indeed, the representationalist belief in the power of words to mirror preexisting phenomena is the metaphysical substrate that supports social constructivist, as well as traditional realist, beliefs. Significantly, social constructivism has been the object of intense scrutiny within both feminist and science studies circles where considerable and informed dissatisfaction has been voiced.[1]

A *performative* understanding of discursive practices challenges the representationalist belief in the power of words to represent preexisting things. Performativity, properly construed, is not an invitation to turn everything (including material bodies) into words; on the contrary, performativity is precisely a contestation of the excessive power granted to language to determine what is real. Hence, in ironic contrast to the misconception that would equate performativity with a form of linguistic monism that takes language to be the stuff of reality, performativity is actually a contestation of the unexamined habits of mind that grant language and other forms of representation more power in determining our ontologies than they deserve.[2]

The move toward performative alternatives to representationalism shifts the focus from questions of correspondence between descriptions and reality (e.g., do they mirror nature or culture?) to matters of practices/doings/actions. I would argue that these approaches also bring to the forefront important questions of ontology, materiality, and agency, while social constructivist approaches get caught up in the geometrical optics of reflection where, much like the infinite play of images between two facing mirrors, the epistemological gets bounced back and forth, but nothing more is seen. Moving away from the representationalist trap of geometrical optics, I shift the focus to physical optics, to questions of diffraction rather than reflection. Diffractively reading the insights of feminist and queer theory and science studies approaches through one another entails thinking the "social" and the "scientific" together in an illuminating way. What often appears as separate entities (and separate sets of concerns) with sharp edges does not actually entail a relation of absolute exteriority at all. Like the diffraction patterns illuminating the indefinite nature of boundaries-displaying shadows in "light" regions and bright spots in "dark" regions—the relation of the social and the scientific is a relation of "exteriority within." This is not a static relationality but a doing—the enactment of boundaries—that always entails constitutive exclusions and there fore requisite questions of accountability.[3] My aim is to contribute to efforts to sharpen the theoretical tool of performativity for science studies and feminist and queer theory endeavors alike, and to promote their mutual consideration. In this article, I offer an elaboration of performativity—a materialist, naturalist, and posthumanist elaboration—that allows matter its due as an active participant in the world's becoming, in its ongoing "intra activity."[4] It is vitally important that we understand how matter matters.

FROM REPRESENTATIONALISM TO PERFORMATIVITY

> People represent. That is part of what it is to be a person. . . . Not *homo faber,* I say, but *homo depictor.*
>
> —Ian Hacking 1983, 144, 132

Liberal social theories and theories of scientific knowledge alike owe much to the idea that the world is composed of individuals—presumed to exist before the law, or the discovery of the law—awaiting/inviting representation. The idea that beings exist as individuals with inherent attributes, anterior to their representation, is a metaphysical presupposition that underlies the belief in political, linguistic, and epistemological forms of representationalism.

Or, to put the point the other way around, representationalism is the belief in the ontological distinction between representations and that which they purport to represent; in particular, that which is represented is held to be independent of all practices of representing. That is, there are assumed to be two distinct and independent kinds of entities—representations and entities to be represented. The system of representation is sometimes explicitly theorized in terms of a tripartite arrangement. For example, in addition to knowledge (i.e., representations), on the one hand, and the known (i.e., that which is purportedly represented), on the other, the existence of a knower (i.e., some one who does the representing) is sometimes made explicit. When this happens it becomes clear that representations serve a mediating function between independently existing entities. This taken-for-granted ontological gap generates questions of the accuracy of representations. For example, does scientific knowledge accurately represent an independently existing reality? Does language accurately represent its referent? Does a given political representative, legal counsel, or piece of legislation accurately represent the interests of the people allegedly represented?

Representationalism has received significant challenge from feminists, poststructuralists, postcolonial critics, and queer theorists. The names of Michel Foucault and Judith Butler are frequently associated with such questioning. Butler sums up the problematics of political representationalism as follows:

> Foucault points out that juridical systems of power *produce* the subjects they subsequently come to represent. Juridical notions of power appear to regulate political life in purely negative terms. . . . But the subjects regulated by such structures are, by virtue of being subjected to them, formed, defined, and reproduced in accordance with the requirements of those structures. If this analysis is right, then the juridical formation of language and politics that represents women as "the subject" of feminism is itself a discursive formation and effect of a given version of representationalist politics. And the feminist subject turns out to be discursively constituted by the very political system that is supposed to facilitate its emancipation. (1990, 2)

In an attempt to remedy this difficulty, critical social theorists struggle to formulate understandings of the possibilities for political intervention that go beyond the framework of representationalism.

The fact that representationalism has come under suspicion in the do main of science studies is less well known but of no less significance. Critical examination of representationalism did not emerge until the study of science shifted its focus from the nature and production of scientific knowledge to the study of the detailed dynamics of the actual practice of science. This significant shift is one way to coarsely characterize the difference in emphasis between separate multiple disciplinary studies of science (e.g., history of science, philosophy of science, sociology of science) and science studies. This is not to say that all science studies approaches are critical of representationalism; many such studies accept representationalism unquestioningly. For example, there are countless studies on the nature of scientific representations (including how scientists produce them, interpret them, and otherwise make use of them) that take for granted the underlying philosophical viewpoint that gives way to this focus—namely, representationalism. On the other hand, there has been a concerted effort by some science studies researchers to move beyond representationalism.

Ian Hacking's *Representing and Intervening* (1983) brought the question of the limitations of representationalist thinking about the nature of science to the forefront. The most sustained and thoroughgoing critique of representationalism in philosophy of science and science studies is to be found in the work of philosopher of science Joseph Rouse. Rouse has taken the lead in interrogating the constraints that representationalist thinking places on theorizing the nature of scientific practices.[5] For example, while the hackneyed debate between scientific realism and social constructivism moved frictionlessly from philosophy of science to science studies, Rouse (1996) has pointed out that these adversarial positions have more in common than their proponents acknowledge. Indeed, they share representationalist assumptions that foster such endless debates: both scientific realists and social constructivists believe that scientific knowledge (in its multiple representational forms such as theoretical concepts, graphs, particle tracks, photographic images) mediates our access to the material world; where they differ is on the question of referent, whether scientific knowledge represents things in the world as they really are (i.e., “Nature”) or “objects” that are the product of social activities (i.e., “Culture”), but both groups subscribe to representationalism.

Representationalism is so deeply entrenched within Western culture that it has taken on a commonsense appeal. It seems inescapable, if not downright natural. But representationalism (like “nature itself,” not merely our representations of it!) has a history. Hacking traces the philosophical problem of representations to the Democritean dream of atoms and the void. According to Hacking’s anthropological philosophy, representations were unproblematic prior to Democritus: “the word ‘real’ first meant just unqualified likeness” (142). With Democritus’s atomic theory emerges the possibility of a gap between representations and represented—”appearance” makes its first appearance. Is the table a solid mass made of wood or an aggregate of discrete entities moving in the void? Atomism poses the question of which representation is real. The problem of realism in philosophy is a product of the atomistic worldview.

Rouse identifies representationalism as a Cartesian by-product—a particularly inconspicuous consequence of the Cartesian division between “internal” and “external” that breaks along the line of the knowing subject. Rouse brings to light the asymmetrical faith in word over world that underlines the nature of Cartesian doubt:

> I want to encourage doubt about [the] presumption that representations (that is, their meaning or content) are more accessible to us than the things they supposedly represent. If there is no magic language through which we can unerringly reach out directly to its referents, why should we think there is nevertheless a language that magically enables us to reach out directly to its sense or representational content? The presumption that we can know what we mean, or what our verbal performances say, more readily than we can know the objects those sayings are about is a Cartesian legacy, a linguistic variation on Descartes’ insistence that we have a direct and privileged access to the contents of our thoughts that we lack towards the “external” world. (1996, 209)

In other words, the asymmetrical faith in our access to representations over things is a contingent fact of history and not a logical necessity; that is, it is simply a Cartesian habit of mind. It takes a healthy skepticism toward Cartesian doubt to be able to begin to see an alternative.[6]

Indeed, it is possible to develop coherent philosophical positions that deny that there are representations on the one hand and ontologically separate entities awaiting representation on the other. A performative understanding, which shifts the focus from linguistic representations to discursive practices, is one such alternative. In particular, the search for alternatives to social constructivism has prompted performative approaches in feminist and queer studies, as well as in science studies. Judith Butler's name is most often associated with the term *performativity* in feminist and queer theory circles. And while Andrew Pickering has been one of the very few science studies scholars to take ownership of this term, there is surely a sense in which science studies theorists such as Donna Haraway, Bruno Latour, and Joseph Rouse also propound performative understandings of the nature of scientific practices.[7] Indeed, *performativity* has become a ubiquitous term in literary studies, theater studies, and the nascent interdisciplinary area of performance studies, prompting the question as to whether all performances are performative.[8] In this article, I propose a specifically posthumanist notion of performativity-one that incorporates important material and discursive, social and scientific, human and nonhuman, and natural and cultural factors. A posthumanist account calls into question the givenness of the differential categories of "human" and "nonhuman," examining the practices through which these differential boundaries are stabilized and destabilized.[9] Donna Haraway's scholarly opus—from primates to cyborgs to companion species—epitomizes this point.

If performativity is linked not only to the formation of the subject but also to the production of the matter of bodies, as Butler's account of "materialization" and Haraway's notion of "materialized refiguration" suggest, then it is all the more important that we understand the nature of this production.[10] Foucault's analytic of power links discursive practices to the materiality of the body. However, his account is constrained by several important factors that severely limit the potential of his analysis and Butler's performative elaboration, thereby forestalling an understanding of precisely *how* discursive practices produce material bodies.

If Foucault, in queering Marx, positions the body as the locus of productive forces, the site where the large-scale organization of power links up with local practices, then it would seem that any robust theory of the materialization of bodies would necessarily take account of *how the body's materiality*—for example, its anatomy and physiology—and *other material forces actively matter to the processes of materialization.* Indeed, as Foucault makes crystal clear in the last chapter of *The History of Sexuality* (vol. I), he is not out to deny the relevance of the physical body but, on the contrary, to

> show how the deployments of power are directly connected to the body-to bodies, functions, physiological processes, sensations, and pleasures; far from the body having to be effaced, what is needed is to make it visible through an analysis in which the biological and the historical are not consecutive to one another . . . but are bound together in an increasingly complex fashion in accordance with the development of the modern technologies of power that take life as their objective. Hence, I do not envision a "history of mentalities" that would take account of bodies only through the manner in which they have been perceived and given meaning and value; but a "history of bodies" and the manner in which what is most material and most vital in them has been invested. (1980a, 151–52)

On the other hand, Foucault does not tell us in what way the biological and the historical are "bound together" such that one is not consecutive to the other. What is it about the materiality of bodies that makes it susceptible to the enactment of biological and historical forces simultaneously? To what degree does the matter of bodies have its own historicity? Are social forces the only ones susceptible to change? Are not biological forces in some sense always already historical ones? Could it be that there is some important sense in which historical forces are always already biological? What would it mean to even ask such a question given the strong social constructivist undercurrent in certain interdisciplinary circles in the early twenty-first century? For all Foucault's emphasis on the political anatomy of disciplinary power, he too fails to offer an account of the body's historicity in which its very materiality plays an *active* role in the workings of power. This implicit reinscription of matter's passivity is a mark of extant elements of representationalism that haunt his largely post representationalist account.[11] This deficiency is importantly related to his failure to theorize the relationship between "discursive" and "nondiscursive" practices. As materialist feminist theorist Rosemary Hennessey insists in offering her critique of Foucault, "a rigorous materialist theory of the body cannot stop with the assertion that the body is always discursively constructed. It also needs to explain how the discursive construction of the body is related to nondiscursive practices in ways that vary widely from one social formation to another" (1993, 46).

Crucial to understanding the workings of power is an understanding of the nature of power in the fullness of its materiality. To restrict power's productivity to the limited domain of the "social," for example, or to figure matter as merely an end product rather than an active factor in further materializations, is to cheat matter out of the fullness of its capacity. How might we understand not only how human bodily contours are constituted through psychic processes but how even the very atoms that make up the biological body come to matter and, more generally, how matter makes itself felt? It is difficult to imagine how psychic and socio historical forces alone could account for the production of matter. Surely it is the case—even when the focus is restricted to the materiality of "human" bodies—that there are "natural," not merely "social," forces that matter. Indeed, there is a host of material-discursive forces including ones that get labeled "social," "cultural," "psychic," "economic," "natural," "physical," "biological," "geopolitical," and "geological"—that may be important to particular (entangled) processes of materialization. If we follow disciplinary habits of tracing disciplinary-defined causes through to the corresponding disciplinary-defined effects, we will miss all the crucial intra-actions among these forces that fly in the face of any specific set of disciplinary concerns.[12]

What is needed is a robust account of the materialization of *all* bodies—" human" and "nonhuman"—and the material-discursive practices by which their differential constitutions are marked. This will require an understanding of the nature of the relationship between discursive practices and material phenomena, an accounting of "nonhuman" as well as "human" forms of agency, and an understanding of the precise causal nature of productive practices that takes account of the fullness of matter's implication in its ongoing historicity. My contribution toward the development of such an understanding is based on a philosophical account that I have been calling "agential realism." Agential realism is an account of technoscientific and other practices that takes feminist, antiracist, poststructuralist, queer, Marxist, science studies, and scientific insights seriously, building specifically on important insights from Niels Bohr, Judith Butler, Michel Foucault, Donna Haraway, Vicki Kirby, Joseph Rouse, and others.[13] It is clearly not possible to fully explicate these ideas here. My more limited goal in this article is to use the notion of performativity as a diffraction grating for reading important insights from feminist and queer studies and science studies through one another while simultaneously proposing a materialist and posthumanist reworking of the notion of performativity. This entails a reworking of the familiar notions of discursive practices, materialization, agency, and causality, among others.

I begin by issuing a direct challenge to the metaphysical underpinnings of representationalism, proposing an agential realist ontology as an alternative. In the following section I offer a posthumanist performative reformulation of the notion of discursive practices and materiality and theorize a specific causal relationship between them. In the final section I discuss the agential realist conceptions of causality and agency that are vital to understanding the productive nature of material-discursive practices, including technoscientific ones.

TOWARD A PERFORMATIVE METAPHYSICS

> *As long as we stick to things and words we can believe that we are speaking of what we see, that we see what we are speaking of, and that the two are linked.*
>
> —Giles Deleuze 1988, 65

> *"Words and things" is the entirely serious title of a problem.*
>
> —Michel Foucault 1972, 49

Representationalism separates the world into the ontologically disjoint domains of words and things, leaving itself with the dilemma of their linkage such that knowledge is possible. If words are untethered from the material world, how do representations gain a foothold? If we no longer believe that the world is teeming with inherent resemblances whose sig natures are inscribed on the face of the world, things already emblazoned with signs, words lying in wait like so many pebbles of sand on a beach there to be discovered, but rather that the knowing subject is enmeshed in a thick web of representations such that the mind cannot see its way to objects that are now forever out of reach and all that is visible is the sticky problem of humanity's own captivity within language, then it begins to become apparent that representationalism is a prisoner of the problematic metaphysics it postulates. Like the frustrated would-be runner in Zeno's paradox, representationalism never seems to be able to get any closer to solving the problem it poses because it is caught in the impossibility of stepping outward from its metaphysical starting place. Perhaps it would be better to begin with a different starting point, a different metaphysics.[14]

Thingification—the turning of relations into "things," "entities," "relata"—infects much of the way we understand the world and our relationship to it.[15] Why do we think that the existence of relations requires relata? Does the persistent distrust of nature, materiality, and the body that pervades much of contemporary theorizing and a sizable amount of the history of Western thought feed off of this cultural proclivity? In this section, I present a relational ontology that rejects the metaphysics of relata, of "words" and "things." On an agential realist account, it is once again possible to acknowledge nature, the body, and materiality in the fullness of their becoming without resorting to the optics of transparency or opacity, the geometries of absolute exteriority or interiority, and the theoretization of the human as either pure cause or pure effect while at the same time remaining resolutely accountable for the role "we" play in the intertwined practices of knowing and becoming.

The postulation of individually determinate entities with inherent properties is the hallmark of atomistic metaphysics. Atomism hails from Democritus.[16] According to Democritus the properties of all things derive from the properties of the smallest unit-atoms (the "uncuttable" or "inseparable"). Liberal social theories and scientific theories alike owe much to the idea that the world is composed of individuals with separately attributable properties. An entangled web of scientific, social, ethical, and political practices, and our understanding of them, hinges on the various/differential instantiations of this presupposition. Much hangs in the balance in contesting its seeming inevitability.

Physicist Niels Bohr won the Nobel Prize for his quantum model of the atom, which marks the beginning of his seminal contributions to the development of the quantum theory.[17] Bohr's philosophy-physics (the two were inseparable for him) poses a radical challenge not only to Newtonian physics but also to Cartesian epistemology and its representationalist triadic structure of words, knowers, and things. Crucially, in a stunning reversal of his intellectual forefather's schema, Bohr rejects the atomistic metaphysics that takes "things" as ontologically basic entities. For Bohr, things do not have inherently determinate boundaries or properties, and words do not have inherently determinate meanings. Bohr also calls into question the related Cartesian belief in the inherent distinction between subject and object, and knower and known.

It might be said that the epistemological framework that Bohr develops rejects both the transparency of language and the transparency of measurement; however, even more fundamentally, it rejects the presupposition that language and measurement perform mediating functions. Language does not represent states of affairs, and measurements do not represent measurement-independent states of being. Bohr develops his epistemological framework without giving in to the despair of nihilism or the sticky web of relativism. With brilliance and finesse, Bohr finds a way to hold on to the possibility of objective knowledge while the grand structures of Newtonian physics and representationalism begin to crumble.

Bohr's break with Newton, Descartes, and Democritus is not based in "mere idle philosophical reflection" but on new empirical findings in the domain of atomic physics that came to light during the first quarter of the twentieth century. Bohr's struggle to provide a theoretical understanding of these findings resulted in his radical proposal that an entirely new epistemological framework is required. Unfortunately, Bohr does not explore crucial ontological dimensions of his insights but rather focuses on their epistemological import. I have mined his writings for his implicit ontological views and have elaborated on them in the development of an agential realist ontology. In this section, I present a quick overview of important aspects of Bohr's account and move on to an explication of an agential realist ontology. This relational ontology is the basis for my post humanist performative account of the production of material bodies. This account refuses the representationalist fixation on "words" and "things" and the problematic of their relationality, advocating instead *a causal relationship between specific exclusionary practices embodied as specific material configurations of the world* (i.e., discursive practices/(con)figurations rather than "words") *and specific material phenomena* (i.e., relations rather than "things"). This causal relationship between the apparatuses of bodily production and the phenomena produced is one of "agential intra-action." The details follow.

According to Bohr, *theoretical concepts* (e.g., "position" and "momentum") are not ideational in character but rather *are specific physical arrangements.*[18] For example, the notion of "position" cannot be presumed to be a well-defined abstract concept, nor can it be presumed to be an inherent attribute of independently existing objects. Rather, "position" only has meaning when a rigid apparatus with fixed parts is used (e.g., a ruler is nailed to a fixed table in the laboratory, thereby establishing a fixed frame of reference for specifying "position"). And furthermore, any measurement of "position" using this apparatus cannot be attributed to some abstract independently existing "object" but rather is a property of the *phenomenon-the* inseparability of "observed object" and "agencies of observation." Similarly, "momentum" is only meaningful as a material arrangement involving movable parts. Hence, the simultaneous indeterminacy of "position" and "momentum" (what is commonly referred to as the Heisenberg uncertainty principle) is a straightforward matter of the material exclusion of "position" and "momentum" arrangements (one requiring fixed parts and the complementary arrangement requiring movable parts).[19]

Therefore, according to Bohr, the primary epistemological unit is not independent objects with inherent boundaries and properties but rather *phenomena.* On my agential realist elaboration, phenomena do not merely mark the epistemological inseparability of "observer" and "observed"; rather, *phenomena are the ontological inseparability of agentially intra-acting "components."* That is, phenomena are ontologically primitive relations—relations without preexisting relata.[20] The notion of *intra action* (in contrast to the usual "interaction," which presumes the prior existence of independent entities/relata) represents a profound conceptual shift. It is through specific agential intra-actions that the boundaries and properties of the "components" of phenomena become determinate and that particular embodied concepts become meaningful. A specific intra-action (involving a specific material configuration of the "apparatus of observation") enacts an *agential cut* (in contrast to the Cartesian cut—an inherent distinction—between subject and object) effecting a separation between "subject" and "object." That is, the agential cut enacts a *local* resolution *within* the phenomenon of the inherent ontological indeterminacy. In other words, relata do not preexist relations; rather, relata-within-phenomena emerge through specific intra-actions. Crucially then, intra-actions enact *agential separability*—the local condition of *exteriority within—phenomena.* The notion of agential separability is of fundamental importance, for in the absence of a classical ontological condition of exteriority between observer and observed it provides the condition for the possibility of objectivity. Moreover, the agential cut enacts a local causal structure among "components" of a phenomenon in the marking of the "measuring agencies" ("effect") by the "measured object" ("cause"). Hence, *the notion of intra-actions constitutes a reworking of the traditional notion of causality.*[21]

In my further elaboration of this agential realist ontology, I argue that phenomena are not the mere result of laboratory exercises engineered by human subjects. Nor can the apparatuses that produce phenomena be understood as observational devices or mere laboratory instruments. Although space constraints do not allow an in-depth discussion of the agential realist understanding of the nature of apparatuses, since apparatuses play such a crucial, indeed constitutive, role in the production of phenomena, I present an overview of the agential realist theoretization of apparatuses before moving on to the question of the nature of phenomena. The proposed elaboration enables an exploration of the implications of the agential realist ontology beyond those specific to understanding the nature of scientific practices. In fact, agential realism offers an understanding of the nature of material-discursive practices, such as those very practices through which different distinctions get drawn, including those between the "social" and the "scientific."[22]

Apparatuses are not inscription devices, scientific instruments set in place before the action happens, or machines that mediate the dialectic of resistance and accommodation. They are neither neutral probes of the natural world nor structures that deterministically impose some particular outcome.

In my further elaboration of Bohr's insights, apparatuses are not mere static arrangements *in* the world, but rather *apparatuses are dynamic (re)configurings of the world, specific agential practices/intra-actions/performances through which specific exclusionary boundaries are enacted.* Apparatuses have no inherent "outside" boundary. This indeterminacy of the "outside" boundary represents the impossibility of closure—the ongoing intra-activity in the iterative reconfiguring of the apparatus of bodily production. Apparatuses are open-ended practices.

Importantly, apparatuses are themselves phenomena. For example, as scientists are well aware, apparatuses are not preformed interchangeable objects that sit atop a shelf waiting to serve a particular purpose. Apparatuses are constituted through particular practices that are perpetually open to rearrangements, rearticulations, and other reworkings. This is part of the creativity and difficulty of doing science: getting the instrumentation to work in a particular way for a particular purpose (which is always open to the possibility of being changed during the experiment as different insights are gained). Furthermore, any particular apparatus is always in the process of intra-acting with other apparatuses, and the enfolding of locally stabilized phenomena (which may be traded across laboratories, cultures, or geopolitical spaces only to find themselves differently materializing) into subsequent iterations of particular practices constitutes important shifts in the particular apparatus in question and therefore in the nature of the intra-actions that result in the production of new phenomena, and so on. Boundaries do not sit still.

With this background we can now return to the question of the nature of phenomena. Phenomena are produced through agential intra-actions of multiple apparatuses of bodily production. Agential intra-actions are specific causal material enactments that may or may not involve "humans." Indeed, it is through such practices that the differential boundaries between "humans" and "nonhumans," "culture" and "nature," the "social" and the "scientific" are constituted. Phenomena are constitutive of reality. Reality is not composed of things-in-themselves or things behind-phenomena but "things"-in-phenomena.[23] The world *is* intra activity in its differential mattering. It is through specific intra-actions that a differential sense of being is enacted in the ongoing ebb and flow of agency. That is, it is through specific intra-actions that phenomena come to matter—in both senses of the word. The world is a dynamic process of intra-activity in the ongoing reconfiguring of locally determinate causal structures with determinate boundaries, properties, meanings, and patterns of marks on bodies. This ongoing flow of agency through which "part" of the world makes itself differentially intelligible to another "part" of the world and through which local causal structures, boundaries, and properties are stabilized and destabilized does not take place in space and time but in the making of spacetime itself. The world is an ongoing open process of mattering through which "mattering" itself acquires meaning and form in the realization of different agential possibilities. Temporality and spatiality emerge in this processual historicity. Relations of exteriority, connectivity, and exclusion are reconfigured. The changing topologies of the world entail an ongoing reworking of the very nature of dynamics.

In summary, the universe is agential intra-activity in its becoming. The primary ontological units are not "things" but phenomena-dynamic topological reconfigurings/entanglements/relationalities/(re)articulations.

And the primary semantic units are not "words" but material-discursive practices through which boundaries are constituted.

This dynamism *is* agency. Agency is not an attribute but the ongoing reconfigurings of the world. On the basis of this performative metaphysics, in the next section I propose a posthumanist refiguration of the nature of materiality and discursivity and the relationship between them, and a posthumanist account of performativity.

A POSTHUMANIST ACCOUNT OF MATERIAL-DISCURSIVE PRACTICES

Discursive practices are often confused with linguistic expression, and meaning is often thought to be a property of words. Hence, discursive practices and meanings are said to be peculiarly human phenomena. But if this were true, how would it be possible to take account of the boundary making practices by which the differential constitution of "humans" and "nonhumans" are enacted? It would be one thing if the notion of constitution were to be understood in purely epistemic terms, but it is entirely unsatisfactory when questions of ontology are on the table. If "humans" refers to phenomena, not independent entities with inherent properties but rather beings in their differential becoming, particular material (re)configurings of the world with shifting boundaries and properties that stabilize and destabilize along with specific material changes in what it means to be human, then the notion of discursivity cannot be founded on an inherent distinction between humans and nonhumans. In this section, I propose a posthumanist account of discursive practices. I also out line a concordant reworking of the notion of materiality and hint at an agential realist approach to understanding the relationship between discursive practices and material phenomena.

Meaning is not a property of individual words or groups of words. Meaning is neither intralinguistically conferred nor extralinguistically referenced. Semantic contentfulness is not achieved through the thoughts or performances of individual agents but rather through particular dis cursive practices. With the inspiration of Bohr's insights, it would also be tempting to add the following agential realist points: meaning is not ideational but rather specific material (re)configurings of the world, and semantic indeterminacy, like ontological indeterminacy, is only locally resolvable through specific intra-actions. But before proceeding, it is probably worth taking a moment to dispel some misconceptions about the nature of discursive practices.

Discourse is not a synonym for language.[24] Discourse does not refer to linguistic or signifying systems, grammars, speech acts, or conversations. To think of discourse as mere spoken or written words forming descriptive statements is to enact the mistake of representationalist thinking. Discourse is not what is said; it is that which constrains and enables what can be said. Discursive practices define what counts as meaningful statements. Statements are not the mere utterances of the originating consciousness of a unified subject; rather, statements and subjects emerge from a field of possibilities. This field of possibilities is not static or singular but rather is a dynamic and contingent multiplicity.

According to Foucault, discursive practices are the local sociohistorical material conditions that enable and constrain disciplinary knowledge practices such as speaking, writing, thinking, calculating, measuring, filtering, and concentrating. Discursive practices produce, rather than merely de scribe, the "subjects" and "objects" of knowledge practices. On Foucault's account these "conditions" are immanent and historical rather than transcendental or phenomenological. That is, they are not conditions in the sense of transcendental, ahistorical, cross-cultural, abstract laws defining the possibilities of experience (Kant), but rather they are actual historically situated social conditions.

Foucault's account of discursive practices has some provocative resonances (and some fruitful dissonances) with Bohr's account of apparatuses and the role they play in the material production of bodies and meanings. For Bohr, apparatuses are particular physical arrangements that give meaning to certain concepts to the exclusion of others; they are the local physical conditions that enable and constrain knowledge practices such as conceptualizing and measuring; they are productive of (and part of) the phenomena produced; they enact a local cut that produces "objects" of particular knowledge practices within the particular phenomena produced. On the basis of his profound insight that "concepts" (which are actual physical arrangements) and "things" do not have determinate boundaries, properties, or meanings apart from their mutual intra-actions, Bohr offers a new epistemological framework that calls into question the dualisms of object/subject, knower/known, nature/culture, and word/world.

Bohr's insight that concepts are not ideational but rather are actual physical arrangements is clearly an insistence on the materiality of meaning making that goes beyond what is usually meant by the frequently heard contemporary refrain that writing and talking are material practices. Nor is Bohr merely claiming that discourse is "supported" or "sustained" by material practices, as Foucault seems to suggest (though the nature of this "support" is not specified), or that nondiscursive (background) practices determine discursive practices, as some existential-pragmatic philosophers purport.[25] Rather, Bohr's point entails a much more intimate relationship between concepts and materiality. In order to better understand the nature of this relationship, it is important to shift the focus from linguistic concepts to discursive practices.

On an agential realist elaboration of Bohr's theoretical framework, apparatuses are not static arrangements in the world that embody particular concepts to the exclusion of others; rather, apparatuses are specific material practices through which local semantic and ontological determinacy are intra-actively enacted. That is, apparatuses are the exclusionary practices of mattering through which intelligibility and materiality are constituted. Apparatuses are material (re)configurings/discursive practices that produce material phenomena in their discursively differentiated becoming. A phenomenon is a dynamic relationality that is locally determinate in its matter and meaning as mutually determined (within a particular phenomenon) through specific causal intra-actions. Outside of particular agential intra-actions, "words" and "things" are indeterminate. Hence, the notions of materiality and discursivity must be reworked in a way that acknowledges their mutual entailment. In particular, on an agential realist account, both materiality and discursive practices are rethought in terms of intra activity.

On an agential realist account, *discursive practices are specific material (re)configurings of the world through which local determinations of boundaries, properties, and meanings are differentially enacted. That is, discursive practices are ongoing agential intra-actions of the world through which local determinacy is enacted within the phenomena produced. Discursive practices are causal intra-actions—they* enact local causal structures through which one "component" (the "effect") of the phenomenon is marked by another "component" (the "cause") in their differential articulation. Meaning is not a property of individual words or groups of words but an ongoing performance of the world in its differential intelligibility. In its causal intra activity, "part" of the world becomes determinately bounded and propertied in its emergent intelligibility to another "part" of the world. Discursive practices are boundary-making practices that have no finality in the ongoing dynamics of agential intra-activity.

Discursive practices are not speech acts, linguistic representations, or even linguistic performances, bearing some unspecified relationship to material practices. Discursive practices are not anthropomorphic place holders for the projected agency of individual subjects, culture, or language. Indeed, they are not human-based practices. On the contrary, agential realism's posthumanist account of discursive practices does not fix the boundary between "human" and "nonhuman" before the analysis ever gets off the ground but rather enables (indeed demands) a genealogical analysis of the discursive emergence of the "human." "Human bodies" and "human subjects" do not preexist as such; nor are they mere end products. "Humans" are neither pure cause nor pure effect but part of the world in its open-ended becoming.

Matter, like meaning, is not an individually articulated or static entity. Matter is not little bits of nature, or a blank slate, surface, or site passively awaiting signification; nor is it an uncontested ground for scientific, feminist, or Marxist theories. Matter is not a support, location, referent, or source of sustainability for discourse. Matter is not immutable or passive. It does not require the mark of an external force like culture or history to complete it. Matter is always already an ongoing historicity.[26]

On an agential realist account, matter does not refer to a fixed substance; rather, *matter is substance in its intra-active becoming—not a thing, but a doing, a congealing of agency. Matter is a stabilizing and destabilizing process of iterative intra-activity.* Phenomena—the smallest material units (relational "atoms")—come to matter through this process of ongoing intra-activity. That is, *matter refers to the materiality/materialization of phenomena,* not to an inherent fixed property of abstract independently existing objects of Newtonian physics (the modernist realization of the Democritean dream of atoms and the void).

Matter is not simply "a kind of citationality" (Butler 1993, 15), the surface effect of human bodies, or the end product of linguistic or dis cursive acts. Material constraints and exclusions and the material dimensions of regulatory practices are important factors in the process of materialization. The dynamics of intra-activity entails matter as an *active* "agent" in its ongoing materialization.

Boundary-making practices, that is, discursive practices, are fully implicated in the dynamics of intra-activity through which phenomena come to matter. In other words, materiality is discursive (i.e., material phenomena are inseparable from the apparatuses of bodily production: matter emerges out of and includes as part of its being the ongoing reconfiguring of boundaries), just as discursive practices are always already material (i.e., they are ongoing material (re)configurings of the world). Discursive practices and material phenomena do not stand in a relationship of externality to one another; rather, the material and the discursive are mutually implicated in the dynamics of intra-activity. But nor are they reducible to one another. The relationship between the material and the discursive is one of mutual entailment. Neither is articulated/articulable in the absence of the other; matter and meaning are mutually articulated. Neither discursive practices nor material phenomena are ontologically or epistemologically prior. Neither can be explained in terms of the other. Neither has privileged status in determining the other.

Apparatuses of bodily production and the phenomena they produce are material-discursive in nature. *Material-discursive practices are specific iterative enactments—agential intra-actions—through which matter is differentially engaged and articulated* *(in the emergence of boundaries and meanings), reconfiguring the material-discursive field of possibilities in the iterative dynamics of intra-activity that is agency.* Intra-actions are causally constraining nondeterministic enactments through which matter-in-the process-of-becoming is sedimented out and enfolded in further materializations.[27]

Material conditions matter, not because they "support" particular discourses that are the actual generative factors in the formation of bodies but rather because *matter comes to matter* through the iterative intra activity of the world in its becoming. The point is not merely that there are important material factors in addition to discursive ones; rather, the issue is the conjoined material-discursive nature of constraints, conditions, and practices. The fact that material and discursive constraints and exclusions are intertwined points to the limited validity of analyses that attempt to determine individual effects of material or discursive factors.[28]

Furthermore, the conceptualization of materiality offered by agential realism makes it possible to take account of material constraints and conditions once again without reinscribing traditional empiricist assumptions concerning the transparent or immediate given-ness of the world and without falling into the analytical stalemate that simply calls for a recognition of our mediated access to the world and then rests its case. The ubiquitous pronouncements proclaiming that experience or the material world is "mediated" have offered precious little guidance about how to proceed. The notion of mediation has for too long stood in the way of a more thoroughgoing accounting of the empirical world. The reconceptualization of materiality offered here makes it possible to take the empirical world seriously once again, but this time with the understanding that the objective referent is phenomena, not the seeming "immediately given-ness" of the world.

All bodies, not merely "human" bodies, come to matter through the world's iterative intra-activity-its performativity. This is true not only of the surface or contours of the body but also of the body in the fullness of its physicality, including the very "atoms" of its being. Bodies are not objects with inherent boundaries and properties; they are material-discursive phenomena. "Human" bodies are not inherently different from "nonhuman" ones. What constitutes the "human" (and the "nonhuman") is not a fixed or pregiven notion, but nor is it a free-floating ideality. What is at issue is not some ill-defined process by which human-based linguistic practices (materially supported in some unspecified way) manage to produce substantive bodies/bodily substances but rather a material dynamics of intra-activity: material apparatuses produce material phenomena through specific causal intra actions, where "material" is always already material-discursive—that *is what it means to matter.* Theories that focus exclusively on the materialization of "human" bodies miss the crucial point that the very practices by which the differential boundaries of the "human" and the "nonhuman" are drawn are always already implicated in particular materializations. The differential constitution of the "human" ("non human") is always accompanied by particular exclusions and always open to contestation. This is a result of the nondeterministic causal nature of agential intra-actions, a crucial point that I take up in the next section.

THE NATURE OF PRODUCTION AND THE PRODUCTION OF NATURE: AGENCY AND CAUSALITY

What is the nature of causality on this account? What possibilities exist for agency, for intervening in the world's becoming? Where do the issues of responsibility and accountability enter in?

Agential intra-actions are causal enactments. Recall that an agential cut effects a local separability of different “component parts” of the phenomenon, one of which (“the cause”) expresses itself in effecting and marking the other (“the effect”). In a scientific context this process is known as a “measurement.” (Indeed, the notion of “measurement” is nothing more or less than a causal intra-action.)[29] Whether it is thought of as a “measurement,” or as part of the universe making itself intelligible to another part in its ongoing differentiating intelligibility and materialization, is a matter of preference.[30] Either way, what is important about causal intra actions is the fact that marks are left on bodies. Objectivity means being accountable to marks on bodies.

This causal structure differs in important respects from the common choices of absolute exteriority and absolute interiority and of determinism and free will. In the case of the geometry of absolute exteriority, the claim that cultural practices produce material bodies starts with the metaphysical presumption of the ontological distinction of the former set from the latter. The inscription model of constructivism is of this kind: culture is figured as an external force acting on passive nature. There is an ambiguity in this model as to whether nature exists in any prediscursive form prior to its marking by culture. If there is such an antecedent entity then its very existence marks the inherent limit of constructivism. In this case, the rhetoric should be softened to more accurately reflect the fact that the force of culture “shapes” or “inscribes” nature but does not materially *produce* it. On the other hand, if there is no preexistent nature, then it behooves those who advocate such a theory to explain how it is that culture can materially produce that from which it is allegedly ontologically distinct, namely nature. What is the mechanism of this production? The other usual alternative is also not attractive: the geometry of absolute interiority amounts to a reduction of the effect to its cause, or in this case nature to culture, or matter to language, which amounts to one form or another of idealism.

Agential separability presents an alternative to these unsatisfactory options.[31] It postulates a sense of “exteriority within,” one that rejects the previous geometries and opens up a much larger space that is more appropriately thought of as a changing topology.[32] More specifically, *agential separability* is a matter of *exteriority within (material-discursive) phenomena.* Hence, no priority is given to either materiality or discursivity.[33] There is no geometrical relation of absolute exteriority between a “causal apparatus” and a “body effected,” nor an idealistic collapse of the two, but rather an ongoing topological dynamics that enfolds the spacetime manifold upon itself, a result of the fact that the apparatuses of bodily production (which are themselves phenomena) are (also) part of the phenomena they produce. Matter plays an active, indeed agential, role in its iterative materialization, but this is not the only reason that the space of agency is much larger than that postulated in many other critical social theories.[34] Intra-actions always entail particular exclusions, and exclusions foreclose any possibility of determinism, providing the condition of an open future.[35] Therefore, intra-actions are constraining but not deter mining. That is, intra-activity is neither a matter of strict determinism nor unconstrained freedom. The future is radically open at every turn. This open sense of futurity does not depend on the clash or collision of cultural demands; rather, it is inherent in the nature of intra-activity—even when apparatuses are primarily reinforcing, agency is not foreclosed. Hence, the notion of intra-actions reformulates the traditional notion of causality and opens up a space, indeed a relatively large space, for material-discursive forms of agency.

A posthumanist formulation of performativity makes evident the importance of taking account of "human," "nonhuman," and "cyborgian" forms of agency (indeed all such material-discursive forms). This is both possible and necessary because agency is a matter of changes in the apparatuses of bodily production, and such changes take place through various intra-actions, some of which remake the boundaries that delineate the differential constitution of the "human." Holding the category "human" fixed excludes an entire range of possibilities in advance, eliding important dimensions of the workings of power.

On an agential realist account, agency is cut loose from its traditional humanist orbit. Agency is not aligned with human intentionality or subjectivity. Nor does it merely entail resignification or other specific kinds of moves within a social geometry of antihumanism. Agency is a matter of intra-acting; it is an enactment, not something that someone or something has. Agency cannot be designated as an attribute of "subjects" or "objects" (as they do not preexist as such). Agency is not an attribute whatsoever-it is "doing"/"being" in its intra-activity. Agency is the enactment of iterative changes to particular practices through the dynamics of intra-activity. Agency is about the possibilities and account ability entailed in reconfiguring material-discursive apparatuses of bodily production, including the boundary articulations and exclusions that are marked by those practices in the enactment of a causal structure. Particular possibilities for acting exist at every moment, and these changing possibilities entail a responsibility to intervene in the world's becoming, to contest and rework what matters and what is excluded from mattering.

CONCLUSIONS

Feminist studies, queer studies, science studies, cultural studies, and critical social theory scholars are among those who struggle with the difficulty of coming to terms with the weightiness of the world. On the one hand, there is an expressed desire to recognize and reclaim matter and its kindred reviled Others exiled from the familiar and comforting domains of culture, mind, and history, not simply to altruistically advocate on behalf of the subaltern but in the hopes of finding a way to account for our own finitude. Can we identify the limits and constraints, if not the grounds, of discourse-knowledge in its productivity? But despite its substance, in the end, according to many contemporary attempts at its salvation, it is not matter that reels in the unruliness of infinite possibilities; rather, it is the very existence of finitude that gets defined as matter. Caught once again looking at mirrors, it is either the face of transcendence or our own image. It is as if there are no alternative ways to conceptualize matter: the only options seem to be the naivete of empiricism or the same old narcissistic bedtime stories.

I have proposed a posthumanist materialist account of performativity that challenges the positioning of materiality as either a given or a mere effect of human agency. On an agential realist account, materiality is an active factor in processes of materialization. Nature is neither a passive surface awaiting the mark of culture nor the end product of cultural performances. The belief that nature is mute and immutable and that all prospects for significance and change reside in culture is a reinscription of the nature/culture dualism that feminists have actively contested. Nor, similarly, can a human/nonhuman distinction be hardwired into any theory that claims to take account of matter in the fullness of its historicity. Feminist science studies scholars in particular have emphasized that foundational inscriptions of the nature/culture dualism foreclose the understanding of how "nature" and "culture" are formed, an understanding that is crucial to both feminist and scientific analyses. They have also emphasized that the notion of "formation" in no way denies the material reality of either "nature" or "culture." Hence, any performative account worth its salt would be ill advised to incorporate such anthropocentric values in its foundations.

A crucial part of the performative account that I have proposed is a rethinking of the notions of discursive practices and material phenomena and the relationship between them. On an agential realist account, dis cursive practices are not human-based activities but rather specific material (re)configurings of the world through which local determinations of boundaries, properties, and meanings are differentially enacted. And matter is not a fixed essence; rather, matter is substance in its intra-active becoming-not a thing but a doing, a congealing of agency. And performativity is not understood as iterative citationality (Butler) but rather iterative intra-activity.

On an agential realist account of technoscientific practices, the "knower" does not stand in a relation of absolute externality to the natural world being investigated—there is no such exterior observational point.[36]

It is therefore not absolute exteriority that is the condition of possibility for objectivity but rather agential separability-exteriority within phenomena.[37] "We" are not outside observers of the world. Nor are we simply located at particular places *in* the world; rather, we are part *of the* world in its ongoing intra-activity. This is a point Niels Bohr tried to get at in his insistence that our epistemology must take account of the fact that we are a part of that nature we seek to understand. Unfortunately, how ever, he cuts short important posthumanist implications of this insight in his ultimately humanist understanding of the "we." Vicki Kirby eloquently articulates this important posthumanist point: "I'm trying to complicate the locatability of human identity as a here and now, an enclosed and finished product, a causal force upon Nature. Or even . . . as something within Nature. I don't want the human to be in Nature, as if Nature is a container. Identity is inherently unstable, differentiated, dispersed, and yet strangely coherent. If I say 'this is Nature itself,' an expression that usually denotes a prescriptive essentialism and that's why we avoid it, I've actually animated this 'itself' and even suggested that 'thinking' isn't the other of nature. Nature performs itself differently."[38]

The particular configuration that an apparatus takes is not an arbitrary construction of "our" choosing; nor is it the result of causally deterministic power structures. "Humans" do not simply assemble different apparatuses for satisfying particular knowledge projects but are themselves specific local parts of the world's ongoing reconfiguring. To the degree that laboratory manipulations, observational interventions, concepts, or other human practices have a role to play it is as part of the material configuration of the world in its intra-active becoming. "Humans" are part of the world body space in its dynamic structuration.

There is an important sense in which practices of knowing cannot be fully claimed as human practices, not simply because we use nonhuman elements in our practices but because knowing is a matter of part of the world making itself intelligible to another part. Practices of knowing and being are not isolatable, but rather they are mutually implicated. We do not obtain knowledge by standing outside of the world; we know because "we" are *of* the world. We are part of the world in its differential becoming. The separation of epistemology from ontology is a reverberation of a metaphysics that assumes an inherent difference between human and nonhuman, subject and object, mind and body, matter and discourse. *Onto-epistem-ology*—the study of practices of knowing in being—is probably a better way to think about the kind of understandings that are needed to come to terms with how specific intra-actions matter.

NOTES

1. Dissatisfaction surfaces in the literature in the 1980s. See, e.g., Donna Haraway's "Gender for a Marxist Dictionary: The Sexual Politics of a Word" (originally published 1987) and "Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective" (originally published 1988); both reprinted in Haraway 1991. See also Butler 1989.
2. This is not to dismiss the valid concern that certain specific performative accounts grant too much power to language. Rather, the point is that this is not an inherent feature of performativity but an ironic malady.
3. Haraway proposes the notion of diffraction as a metaphor for rethinking the geometry and optics of relationality: "[F]eminist theorist Trinh Minh-ha . . . was looking for a way to figure 'difference' as a 'critical difference within,' and not as special taxonomic marks grounding difference as apartheid. . . . Diffraction does not produce 'the same' displaced, as reflection and refraction do. Diffraction is a mapping of interference, not of replication, reflection, or reproduction. A diffraction pattern does not map where differences appear, but rather maps where the *effects* of differences appear" (1992, 300). Haraway (1997) promotes the notion of diffraction to a fourth semiotic category. Inspired by her suggestions for usefully deploying this rich and fascinating physical phenomenon to think about differences that matter, I further elaborate the notion of diffraction as a mutated critical tool of analysis (though not as a fourth semiotic category) in my forthcoming book (Barad forthcoming).
4. See Rouse 2002 on rethinking naturalism. The neologism *intra-activity* is defined below.
5. Rouse begins his interrogation of representationalism in *Knowledge and Power* (1987). He examines how a representationalist understanding of knowledge gets in the way of understanding the nature of the relationship between power and knowledge. He continues his critique of representationalism and the development of an alternative understanding of the nature of scientific practices in *Engaging Science* (1996). Rouse proposes that we understand science practice as ongoing patterns of situated activity, an idea that is then further elaborated in *How Scientific Practices Matter* (2002).
6. The allure of representationalism may make it difficult to imagine alternatives. I discuss performative alternatives below, but these are not the only ones. A concrete historical example may be helpful at this juncture. Foucault points out that in sixteenth-century Europe, language was not thought of as a medium; rather, it was simply "one of the figurations of the world" (1970, 56), an idea that reverberates in a mutated form in the posthumanist performative account that I offer.
7. Andrew Pickering (1995) explicitly eschews the representationalist idiom in favor of a performative idiom. It is important to note, however, that Pickering's notion of performativity would not be recognizable as such to poststructuralists, despite their shared embrace of *performativity* as a remedy to representationalism, and despite their shared rejection of humanism. Pickering's appropriation of the term does not include any acknowledgement of its politically important-arguably inherently queer-genealogy (see Sedgwick 1993) or why it has been and continues to be important to contemporary critical theorists, especially feminist and queer studies scholars/activists. Indeed, he evacuates its important political historicity along with many of its crucial insights. In particular, Pickering ignores important discursive dimensions, including questions of meaning, intelligibility, significance, identity formation, and power, which are central to poststructuralist invocations of "performativity." And he takes for granted the humanist notion of agency as a *property* of individual entities (such as humans, but also weather systems, scallops, and stereos), which poststructuralists problematize. On the other hand, poststructuralist approaches fail to take account of "nonhuman agency," which is a central focus of Pickering's account. See Barad (forthcoming) for a more detailed discussion.
8. The notion of performativity has a distinguished career in philosophy that most of these multiple and various engagements acknowledge. Performativity's lineage is generally traced to the British philosopher J. L. Austin's interest in speech acts, particularly the relationship between saying and doing. Jacques Derrida is usually cited next as offering important poststructuralist amendments. Butler elaborates Derrida's notion of performativity through Foucault's understanding of the productive effects of regulatory power in theorizing the notion of identity performatively. Butler introduces her notion of gender performativity

in *Gender Trouble,* where she proposes that we understand gender not as a thing or a set of free-floating attributes, not as an essence—but rather as a "doing": "gender is itself a kind of becoming or activity . . . gender ought not to be conceived as a noun or a substantial thing or a static cultural marker, but rather as an incessant and repeated action of some sort" (1990, 112). In *Bodies That Matter* (1993) Butler argues for a linkage between gender performativity and the materialization of sexed bodies. Eve Kosofsky Sedgwick (1993) argues that performativity's genealogy is inherently queer.

9. This notion of posthumanism differs from Pickering's idiosyncratic assignment of a *"posthumanist* space [as] a space in which the human actors are still there but now inextricably entangled with the nonhuman, no longer at the center of the action calling the shots" (26). However, the decentering of the human is but one element of posthumanism. (Note that Pickering's notion of "entanglement" is explicitly epistemological, not ontological. What is at issue for him in dubbing his account "posthumanist" is the fact that it is attentive to the mutual accommodation, or responsiveness, of human and nonhuman agents.)
10. It could be argued that "materialized refiguration" is an *enterprised up* (Haraway's term) version of "materialization," while the notion of "materialization" hints at a richer account of the former. Indeed, it is possible to read my posthumanist performative account along these lines, as a diffractive elaboration of Butler's and Haraway's crucial insights.
11. See also Butler 1989.
12. The conjunctive term *material-discursive* and other agential realist terms like *intra-action* are defined below
13. This essay outlines issues I developed in earlier publications including Barad 1996, l998a, l998b, 200lb, and in my forthcoming book (Barad forthcoming).
14. It is no secret that *metaphysics* has been a term of opprobrium through most of the twentieth century. This positivist legacy lives on even in the heart of its detractors. Post-structuralists are simply the newest signatories of its death warrant. Yet, however strong one's dislike of metaphysics, it will not abide by any death sentence, and so it is ignored at one's peril. Indeed, new "experimental metaphysics" research is taking place in physics laboratories in the United States and abroad, calling into question the common belief that there is an inherent boundary between the "physical" and the "metaphysical" (see Barad forthcoming). This fact should not be too surprising to those of us who remember that the term *metaphysics* does not have some highbrow origins in the history of philosophy but, rather, originally referred to the writings of Aristotle that came after his writings on physics, in the arrangement made by Andronicus of Rhodes about three centuries after Aristotle's death.
15. *Relata* are would-be antecedent components of relations. According to metaphysical atomism, individual relata always preexist any relations that may hold between them.
16. Atomism is said to have originated with Leucippus and was further elaborated by Democritus, devotee of democracy, who also explored its anthropological and ethical implications. Democritus's atomic theory is often identified as the most mature pre-Socratic philosophy, directly influencing Plato and Epicurus, who transmitted it into the early modern period. Atomic theory is also said to form the cornerstone of modern science.
17. Niels Bohr (1885–1962), a contemporary of Einstein, was one of the founders of quantum physics and also the most widely accepted interpretation of the quantum theory, which goes by the name of the Copenhagen interpretation (after the home of Bohr's internationally acclaimed physics institute that bears his name). On my reading of Bohr's philosophy-physics, Bohr can be understood as proposing a protoperformative account of scientific practices.
18. Bohr argues on the basis of this single crucial insight, together with the empirical finding of an inherent discontinuity in measurement "intra-actions," that one must reject the presumed inherent separability of observer and observed, knower and known. See Barad 1996, forthcoming.
19. The so-called uncertainty principle in quantum physics is not a matter of "uncertainty" at all but rather of indeterminacy. See Barad 1995, 1996, forthcoming.
20. That is, relations are not secondarily derived from independently existing "relata," but rather the mutual ontological dependence of "relata"—the relation—is the ontological primitive. As discussed below, relata only exist *within* phenomena as a result of specific intra-actions (i.e., there are no independent relata, only relata-within-relations).
21. A concrete example may be helpful. When light passes through a two-slit diffraction grating and forms a diffraction pattern it is said to exhibit wavelike behavior. But there is also evidence that light exhibits particlelike characteristics, called *photons.* If one wanted to test this hypothesis, the diffraction apparatus could be modified in such

a way as to allow a determination of which slit a given photon passes through (since particles only go through a single slit at a time). The result of running this experiment is that the diffraction pattern is destroyed! Classically, these two results together seem contradictory-frustrating efforts to specify the true ontological nature of light. Bohr resolves this wave-particle duality paradox as follows: the objective referent is not some abstract, independently existing entity but rather the phenomenon of light intra-acting with the apparatus. The first apparatus gives determinate meaning to the notion of "wave," while the second provides determinate meaning to the notion of "particle." The notions of "wave" and "particle" do not refer to inherent characteristics of an object that precedes its intra-action. *There are no such independently existing objects with inherent characteristics.* The two different apparatuses effect different cuts, that is, draw different distinctions delineating the "measured object" from the "measuring instrument." In other words, they differ in their local material resolutions of the inherent ontological indeterminacy. There is no conflict because the two different results mark different intra-actions. See Barad 1996, forthcoming for more details.

22. This elaboration is not based on an analogical extrapolation. Rather, I argue that such anthropocentric restrictions to laboratory investigations are not justified and indeed defy the logic of Bohr's own insights. See Barad forthcoming.
23. Because phenomena constitute the ontological primitives, it makes no sense to talk about independently existing things as somehow behind or as the causes of phenomena. In essence, there are no noumena, only phenomena. Agential realist phenomena are neither Kant's phenomena nor the phenomenologist's phenomena.
24. I am concerned here with the Foucauldian notion of discourse (discursive practices), not formalist and empirical approaches stemming from Anglo-American linguistics, sociolinguistics, and sociology.
25. Foucault makes a distinction between "discursive" and "nondiscursive" practices, where the latter category is reduced to social institutional practices: "The term 'institution' is generally applied to every kind of more-or-less constrained behaviour, everything that functions in a society as a system of constraint and that isn't utterance, in short, *all the field of the non-discursive social, is an institution*" (1980b, 197–98; my italics). This specific social science demarcation is not particularly illuminating in the case of agential realism's posthumanist account, which is not limited to the realm of the social. In fact, it makes no sense to speak of the "nondiscursive" unless one is willing to jettison the notion of causality in its intra-active conception.
26. In her critique of constructivism within feminist theory Judith Butler puts forward an account of materialization that seeks to acknowledge these important points. Reworking the notion of matter as a process of materialization brings to the fore the importance of recognizing matter in its historicity and directly challenges representationalism's construal of matter as a passive blank site awaiting the active inscription of culture and the representationalist positioning of the relationship between materiality and discourse as one of absolute exteriority. Unfortunately, however, Butler's theory ultimately reinscribes matter as a passive product of discursive practices rather than as an active agent participating in the very process of materialization. This deficiency is symptomatic of an incomplete assessment of important causal factors and an incomplete reworking of "causality" in understanding the nature of discursive practices (and material phenomena) in their productivity. Furthermore, Butler's theory of materiality is limited to an account of the materialization of human bodies or, more accurately, to the construction of the contours of the human body. Agential realism's relational ontology enables a further reworking of the notion of materialization that acknowledges the existence of important linkages between discursive practices and material phenomena without the anthropocentric limitations of Butler's theory.
27. The nature of causal intra-actions is discussed further in the next section.
28. See Barad 1998b, 2001a, 2001b, forthcoming for examples.
29. I am grateful to Joe Rouse for putting this point so elegantly (private conversation). Rouse (2002) suggests that *measurement* need not be a term about laboratory operations, that before answering whether or not something is a measurement a prior question must be considered, namely, What constitutes a measurement of what?
30. Intelligibility is not a human-based affair. It is a matter of differential articulations and differential responsiveness/engagement. Vicki Kirby (1997) makes a similar point.
31. Butler also rejects both of these options, proposing an alternative that she calls the "constitutive outside." The "constitutive outside" is an exteriority *within language*—it is the "that which" to which language is impelled to respond in the

repeated attempt to capture the persistent loss or absence of that which cannot be captured. It is this persistent demand for, and inevitable failure of, language to resolve that demand that opens up a space for resignification—a form of agency—within the terms of that reiteration. But the fact that language itself is an enclosure that contains the constitutive outside amounts to an unfortunate reinscription of matter as subservient to the play of language and displays a commitment to an unacceptable anthropocentrism, reducing the possibilities for agency to resignification.

32. Geometry is concerned with shapes and sizes (this is true even of the non-Euclidean varieties, such as geometries built on curved surfaces like spheres rather than on flat planes), whereas topology investigates questions of connectivity and boundaries. Although spatiality is often thought of geometrically, particularly in terms of the characteristics of enclosures (like size and shape), this is only one way of thinking about space. Topological features of manifolds can be extremely important. For example, two points that seem far apart geo metrically may, given a particular connectivity of the spatial manifold, actually be proximate to one another (as, e.g., in the case of cosmological objects called "wormholes").
33. In contrast to Butler's "constitutive outside," for example.
34. For example, the space of agency is much larger than that postulated by Butler's or Louis Althusser's theories. There is more to agency than the possibilities of linguistic resignification, and the circumvention of deterministic outcome does not require a clash of apparatuses/discursive demands (i.e., overdetermination).
35. This is true at the atomic level as well. Indeed, as Bohr emphasizes, the mutual exclusivity of "position" and "momentum" is what makes the notion of causality in quantum physics profoundly different from the determinist sense of causality of classical Newtonian physics.
36. Others have made this point as well, e.g., Haraway 1991; Kirby 1997; Rouse 2002; and Bohr.
37. The notion of agential separability, which is predicated on the agential realist notion of intra-actions, has far-reaching consequences. Indeed, it can be shown to play a critical role in the resolution of the "measurement problem" and other long-standing problems in quantum theory. See Barad forthcoming.
38. Vicki Kirby (private communication, 2002). Kirby's sustained interrogation of the tenacious nature/culture binary is unparalleled. See Kirby 1997 for a remarkable "materialist" (my description) reading of Derridean theory.

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CHAPTER 29

Animal Performances: An Exploration of Intersections between Feminist Science Studies and Studies of Human/Animal Relationships

Lynda Birke, Mette Bryld, and Nina Lykke

INTRODUCTION

Non-human animals are both common and rare in feminist science studies. They are common in the sense that feminist analyses of science have necessarily paid attention to the biological sciences, which both use and define non-human species. But they are rare in the sense that feminist literature in general has paid scant regard to how we think about *animals* specifically (rather than as part of biology in general) or their place in relation to our theory.

Three decades ago, feminist work on science concentrated on women's health and on critiques of biological determinism. Among other things, this determinism typically relied on parallels drawn between stories of animals behaving in particular (instinctive) ways, and gender-stereotypic behaviour in humans. Repudiating these claims inevitably meant that feminists tended to avoid speaking about non-human animals, while emphasizing the social construction of gender, and human uniqueness. Meanwhile, the biological sciences have been a key focus for feminist science studies—the very areas of science which not only help to define what animals are, but also use non-human species extensively in the creation of biological knowledge. In that sense, then, animals have been central to how we have analysed science, yet covertly so.

Although a concern with animals and how we think about them is still relatively rare in feminist theory, they have now begun to enter the literature—admittedly, an entrance more at the pace of a tortoise than a hare (Birke, 2002). This emerging work, which theorizes intersections between feminist theory and animal studies, shows many reasons why feminists should pay attention to how we think about animals and animality, and how humans and non-humans act together in relationship. Animality is, for example, deeply intertwined with concepts of gender, race, or sexuality (Haraway, 1989; Birke, 1994; Bryld and Lykke, 2000). Moreover, 'animality' has long served as a foil to reflect what we consider to be human uniqueness; we often refer, for instance, to 'humans and animals' as though they are quite separate from us and quite homogeneous. That distinction, moreover, is reinforced by disciplinary segregation: sociology has traditionally studied humans and excluded other animals, while nonhumans and their behaviour fall within the remit of biology. What is increasingly clear, however, is that animality itself (or, the specificity of any particular kind of animal) is just as complexly constructed as gender or humanness and so does not readily fall into disciplinary divides.

In this article, we will draw on our background as feminist science studies scholars and explore the intersections between feminist theory and studies of human/animal relationships. Like Karen Barad (2003), we find the concept of 'performativity' useful for analysing co- or intra-actions[1] of human and non-human actors, and we have thus begun to explore its relevance for the study of the human/animal interface, particularly within the discourses of the natural sciences, including those of popular science.[2]

Among other things, we argue that performativity shifts the focus toward ideas of animal agency, and away from oppositional meanings of animal/human toward a more inclusive one.[3]

The article is structured in three main parts. In the first part, we draw parallels between the discourses of gender/sexuality and animality, introducing the idea of 'animaling' to describe how we culturally produce the human/animal divide. We then introduce the concept of performativity, to challenge that division and to provide a fresh way of thinking about humans and animals. In the second part of the article we will illustrate these themes using laboratory rats as an example. In the third section, we ask how feminist theory and human/animal studies may enrich each other, theoretically, using the notion of performativity.

PERFORMATIVITY AS NODAL POINT BETWEEN FEMINIST THEORY AND STUDIES OF HUMAN/ANIMAL RELATIONSHIPS

Judith Butler (1990, 1993) developed the concept of performativity as a key approach to feminist theorizing of queer perspectives, but it can also be used to think about animals and animality, we argue. In Butler's theoretical work, performativity refers to the discursive practices through which human gender and sexuality are enacted in socio-cultural interaction. It indicates how gender as well as sexual identity, consequently, is something we *do* rather than innate and essential capacities that we have or are.

By contrast, in the natural sciences, nonhuman animals have typically been portrayed as beings characterized by innate behaviours, including behaviours determined by sexual difference. Sociality thus emerges incidentally, as a product of individual animals' instinctive responses. So, for example, 'gender differences' in nonhuman animals are almost always seen as the result of individual differences in something intrinsic (genes or hormones); they are very rarely seen as something created by social interaction. This, then, is quite different from how performativity has been used to theorize human gender, as a socio-cultural process. What seems to be missing, in our opinion, as a result of natural science's emphasis on sociality as product of inherent traits in animals, is much sense of nonhuman otherness as a *doing* or *becoming,* produced and reproduced in specific contexts of human/nonhuman interaction—which is where we think that the inspiration from Butler and, more recently, Barad (2003), can be particularly important.

To begin with Butler's work, with its emphasis on linguistic structures, she suggests that discourses of 'queering' act as founding moments of performativity (Butler, 1993); in an approximate analogy, we use the term 'animaling'. Like the discursive regimes which produced the word 'queer', so those that enabled the word 'animal' in its specific sense of being oppositional to 'human' now reproduce power through different pejorative and inferiority-producing strategies. The noun 'queer' emerges from hegemonic discourse, which posits an essential dichotomy between a heterosexual norm and 'queer' deviancy. Analogously, the noun 'animal' is linked to a plethora of hegemonic discourses (philosophical, scientific, etc.), which rely on underlying assumptions about the essence or identity of 'animal' or 'human'. Their effect is to sustain the opposition of Human/cultural subject versus Animal/natural object. '*The* Animal' in these essentializing discourses becomes that which is not Human (i.e., without subjectivity, without intentionality—a mere genetically programmed stimulus-reaction—machine: see discussion in Stibbe, 2001).

We suggest that the verbal form of the noun 'animal'—like the verbal form of 'queer'—can introduce a decisive break with the essentialism of the noun. 'Queering', notes Butler (1993), shifts the focus from an essence, other to the heterosexual norm, to a question of how 'queer' is performed and relates to socio-cultural power relations. Queer is no longer, in this perspective, an essence but a doing. Following a parallel line of thought, the notion of 'animaling' can also shift perspective from animal essences to a study of the material-semiotic performativity of human/animal relationships. Now, there are some differences between these terms. The word 'queer' does cultural work both for those inside and outside specific communities, marking borders for both. To make the word into a verb was a transgressive act precisely because it challenged those borders. Clearly non-human animals are not participants in the very human act of linguistically constructing boundaries, so animaling cannot work in direct analogy to queering across the human/animal boundary.

Linguistic boundaries, however, can be and are maintained by humans in relation to animals. If we shift the focus from groups of individuals, to relationships, we can focus on the human/animal as a kind of hybrid, that exists in the spaces between the two,[4] and which—as a kind of hybrid—can maintain boundaries with other similar hybrids. Like queering, 'animaling' is a discursive process, operating between these human/animal conjunctions (thus no longer across the border of those who use speech and those who do not). For example, how the term 'animal' operates will differ between a human-and-guide-dog dyad, and (say) a human-trapping-rats dyad; the relationship between human and non-human is very different in each case. This could matter in the case of disputed politics, such as disagreements between antivivisectionists, opposed to use of any living animal in research, and those who seek legislative reform, for whom definitions of 'animals' may be contested.[5] So, while it is an inexact analogy, we suggest that 'animaling' can also do border work between these conjoint human/non-humans, just as queering does.

Useful though we believe it is to use these ideas to challenge (human) cultural concepts of animality, our discussion so far has remained at the level of spoken language—by and large, the prerogative of humans. Barad (2003), however, begins her reworking of ideas of performativity by noting that, in recent theoretical work, 'Language has been granted too much power' (p. 801). Relatedly, even though we might seek to challenge the premises on which the concept 'animal' is founded, discussing only how the word is used still leaves non-human animals as rather passive participants in the creation of meaning.

Barad's work seeks to challenge much recent scholarship in which, she notes, ' . . . matters of "fact" (so to speak) have been replaced with matters of signification (no scare quotes here). Language matters. Discourse matters. Culture matters. There is an important sense in which the only thing that does not seem to matter anymore is matter' (Barad, 2003: 801). In trying to move beyond representationalism (the belief that there are representations and things to be represented), she turns to what she calls 'agential realism', using performativity as a concept to move beyond the narrow confines of language. In this move, she refuses separation of observed object and observer, to emphasize instead *phenomena*. Of particular concern to us here, this development of performativity permits inclusion of the material, including animals.

We argue that the notion of performativity can equally be applied to thinking about the intimate choreography of human/animal interrelationships, following Barad's reformulation of the concept. Against this background, we will suggest that the notion of performativity can serve a useful purpose in clarifying how human/animal relationships are co-constructed by discursive practices, to create emergent phenomena (the choreography, so to speak), and thus engaging both humans and non-humans in mutual intra-action.

With that in mind, we turn now to exploring a specific case study of animals in science; in our work, we have analysed several examples, such as the behaviour of insects in documentary films (Lykke and Bryld, 2003) and the behaviour of laboratory rats (Birke, 2003). Here, we use rats as an example—species with whom we also live closely (even if we would prefer not to acknowledge that proximity). But they have entered the laboratory in highly specific ways, engaging in the material development of 'the laboratory rat'. This will bring us on to develop the idea of human/animal performativity more fully, in later sections.

BECOMING RATS: ANIMALS IN SCIENTIFIC DISCOURSE AND LABORATORY PRACTICES

Analysing scientific descriptions of animal behaviour over the past century, Eileen Crist (1999) notes how these have oscillated between two kinds of narrative. One, which she characterizes as internalistic, has historically typified naturalists' writing (including Darwin's): it emphasizes animals as active subjects, and gives a phenomenological description of the animal's life world. It is, moreover, a style in which the observer is often present, writing about personal observations and interactions with the animals. The other style, characterized as externalistic, focuses on scientists' efforts to objectify nature and to remove references to subjectivity.[6] Unlike the stories of individuals typifying the naturalistic tradition, the externalist narratives insist on general terms, in which a single animal stands to represent the whole species, and the observer stands apart.

These two different kinds of narrative configure animals quite differently. In neither is the animal particularly participative, but in the externalist narrative it is almost entirely made passive.[7] As above, we will look first at how rats fare in narrative representations (which have been the focus of research in several science studies), before considering how we can move beyond representations to a position of rat performativity and animal agency.

Some animals have meaning to us humans almost entirely in externalist, scientific terms—the laboratory rat is one example. There is relatively little 'natural history' of the wild rat, so internalist narratives are rare.[8] Yet these are animals having huge significance for us, in folklore and in our history; indeed, given the role of rats as carriers of pandemics such as bubonic plague, there is a very real sense in which they have actively participated in shaping human society as we know it (Hendrickson, 1983). Despite the dearth of rat natural history, lab rats are used in millions in scientific procedures throughout the world. But how do we humans understand the 'laboratory rat'? Not surprisingly, externalist, objectifying, narratives are inevitable. The animals are typically referred to as 'the laboratory rat', as though that descriptor defines a species, and despite the many dissimilarities between rats in laboratories and those in the wild (Birke, 2003).

Meanwhile, lab rats are hidden from view, erased linguistically and materially. They are given numbers ('300 rats were used'); they stand as 'models' for humans; how they live is rarely important enough to include in reports; they are hidden away in ranks of cages in specialized animal houses (Birke and Smith, 1994); their use and deaths are considered more acceptable than the use of many other animals. They become, in some senses, data: what outside the lab might have been a 'naturalistic' animal (like the ones in the sewers) makes a transition to being an 'analytic' animal as parts of their bodies are transformed into laboratory artefacts (such as histology slides: see Lynch, 1988). Not surprisingly, they are frequently referred to as 'laboratory tools' and their development described as creating the 'right tool for the job' (Clarke and Fujimura, 1992).[9]

Lab rats, then, are made discursively into part of the laboratory. But this is much more than mere linguistic turns, for the entry of rats into laboratories is profoundly embedded in a whole industry of activities and institutions. This is where Barad's approach is important, to locate the materiality of the rat in the processes of meaning-making. Rats are, in important senses, agents of their own history, and consequently of the history of scientific knowledge (which owes a very great deal to laboratory animals of all kinds).

However rats first got into laboratories (and some certainly came from the wild), they were soon kept (from the late nineteenth century on) to be bred selectively for laboratory use, to create specific animals to occupy specific locations in relation to laboratory space and practice (Logan, 2001). In that sense, they have come to embody materially a whole set of specific practices—linguistic and material—which define what takes place in laboratories. Their development from the early twentieth century was the materialization of the demand for standardization—epitomizing the demand to be 'more scientific'; in turn, laboratory equipment (cages, stereotaxic equipment to immobilize animals' heads and so on) has evolved to fit standard rats, while rats are further standardized to fit the apparatus. They have, quite literally, been bred to fit the laboratory, its technologies, and its practices (Clause, 1993; Logan, 2001).

Scientists may have specific, intra-active, relationships with rats in the laboratory (see Dewsbury, 1992)—or they may not (if, for instance, someone else handles the rat and produces whatever rat part the scientist wants further away in the laboratory). In either case, rats occupy a complex place in a wide array of material and semiotic practices, *and their own behaviour plays a crucial part.* For instance, strains of rats in the early twentieth century were selected for specific traits, including their sexual precocity and their docility to enable easy handling (Logan, 2001), while a crucial part of laboratory training for humans is how to manage the behaviour of the animal (such that human management of experimental protocols is dictated by the rats' responses: biting and squealing causes problems. See Lynch, 1988). In both senses, rats' behaviour played a crucial part in the development of modern science and the making of scientists.

So, we might apply the concept of performativity here to the behaviour of the rat: the notion of 'lab rat' is a doing, a production of meanings within and outside of science. But, as mentioned earlier, it is important to stress that performativity should be understood as a material-semiotic process in the posthuman sense (Barad, 2003); the rat itself is an agent in the process, whether it obligingly reproduces to order or squeals and bites the experimenter. So too are the technologies (cages, etc.) which produce and are produced by rats-in-laboratories.

Indeed, what we understand as 'the laboratory rat' is something of a hybrid, constituted jointly by the animal, the people and various associated technologies (standard cages; devices for weighing or killing; foodstuffs and so on: see Birke and Michael, 1997). In that sense, 'laboratory rat-ness' is a part performed to fit very precisely into the scientific enterprise; meanings emerge from a nexus of apparatuses, animals and people.[10]

And just as gender is 'the repeated stylization of the body, a set of repeated acts within a highly regulatory frame that congeal over time' (Butler, 1990: 33) and literally embody how we are in the world, so the rat body congeals a whole set of technologies and practices.

Although at first glance, the lab rat seems to be the epitome of obliteration through standardization and the distancing stance of scientific reporting, all of which seem to make it disappear, yet it has been an actor in its own history. Indeed, it is precisely the role of rats as actors that can help to destabilize the human/animal binary. The long history of standardization, use of the passive voice, legal frameworks of animal experimentation,[11] and ethical justifications for using non-human animals—all these operate to maintain a clear discontinuity between humans and other animals. They serve to separate humans from non-humans, both in time and space, and conceptually. Thus even though our culture sometimes includes humans in the category animal (and nowhere is this more clear than in biological sciences, with their belief in evolution), the *practice* of science perpetuates a boundary. On this boundary fence sits the rat, which can at times refuse to play the game of scientific object. Among other things, it can turn round and sink its teeth into the experimenter.

THE PARTICIPATING ANIMAL

The separation of 'animals' from humans, on which we focus here, has a long cultural history, sitting uneasily alongside our reluctant acknowledgement that humans also belong in the larger category 'animal'. But in the practices and discourses of science, that tendency toward separation is at times re-enacted and reinforced, gaining authority and power, whether by objectifying language or the creation of living apparatus. Ironically, separation is happening in the very branch of science whose centrepoint theory, evolution, would emphasize our similarity to, and continuity with, other animals.

Darwin himself, however, might not recognize the style of writing about animals that has come to characterize scientific writing,[12] which became increasingly codified and objectifying throughout the twentieth century (Bazerman, 1988). In her analysis of narrative style in ethological writing, Crist argues that when ethologists and sociobiologists 'displace the language of the lifeworld with a technical idiom, all the elements of the animal world change, and readers find themselves hovering over a very different landscape' (Crist, 1999: 87). This shift, she argues, creates another way of 'seeing' (Crist, 1999: 3).

More recently, however, another way of seeing in natural science is appearing, which seems to permit animals a greater agency. In parallel with the growth in public and academic interest in animal issues, scientific accounts of animals have begun to change. Within ethology (the scientific study of animal behaviour), for example, there is growing recognition that the older image of animals as hard-wired automata is misleading; on the contrary, many kinds of animals are much more self-aware, much more conscious, than we have—in our human arrogance—tended to assume (e.g., Bekoff, 2002; Rogers, 1997). Within this literature, non-human animals are beginning to appear as actors and as subjects of a life, not merely objects of study; they are not simply acting out their instincts but are engaged in complex decisions about their lives. Not surprisingly perhaps the writing style changes, too: it is hard to write about thinking, feeling individuals in distant, objectifying, ways (as Wieder, 1988, noted about laboratory researchers working with chimpanzees).

This perspective changes the construction of ‘the animal’. In particular, understanding ‘what animals do’ when the animals in question are living in close proximity to us (companion animals, for example) means understanding how animals themselves participate. It also means understanding how both human and animal are engaged in mutual decision-making, to create a kind of choreography, a co-creation of behaviour (see Game, 2001; Haraway, 2003; Sanders, 1999). That is not an easy understanding to obtain: empirical studies of human/animal relationships tend to draw from sociology or ethology and inevitably focus primarily on one or other participant rather than the ongoing intra-action.[13] Yet some scholars have begun to ask questions about the *relationship* and its maintenance. Ann Game, for example, writes about the fine tuning of horse–human intra-action in advanced riding, while both Haraway and Sanders write, in different ways, about the development of dog–human relationships. What is clear from these new writings is an emphasis on co-creation, a kind of mutual becoming. We are already, notes Haraway regarding our very close relationships with domestic dogs, deeply biologically entwined and have been ever since dogs first chose to live with us.

What these close associations also mean is that we are intra-acting not with the scientific abstraction *Equus caballus* or *Canis familiaris* when we engage with horses or dogs, for example. On the contrary, these are no longer to be understood only in terms of their wild counterparts, but as something else. In that sense, the sociological studies which have looked at (say) human relationships with specific breeds of dogs are closer to the relationship than those natural scientific studies which continue to abstract to the wild species. Herds of wild horses on the Mongolian steppes[14] do not have so much in common with selectively bred competition horses, engaging daily with humans.

It is in the close associations of humans/animal companions that the animal’s participation in performativity becomes most clear. If performativity is repetitions consolidated over time (Butler, 1990: 33), then how we intra-act with companion animals sharing our lives (and some other animals besides) is clearly performative. If we speak of the ‘animality’ of, say, a dog, we draw partly on multiple cultural representations of dogs and other non-humans. But we also infer an embodiment of the lifelong intraaction of dog with human: from its very first breath, a puppy is usually engaging in a combined doghuman world.

Infant horses, similarly, must in our culture learn to socialize both with their mother and other horses, *and also* with humans, who must themselves learn how to socialize with horses. Later, when the horse is ridden, both horse and rider perform together in repeated acts which ‘congeal over time’ to create what Ann Game calls ‘embodying the centaur’ (Game: 2001). This is a materialization, such that both horse and human bodies *are changed;* riders seem to carry within their bodies subtle knowledge of how horses react—as do horses of human riders.[15] Nervous impulses and muscle twitches have become transformed, new material-semiotic practices created. In so doing, a hybrid is created—a hybrid which itself can have its own performativities and relationships to other social and cultural institutions.

In such cases of non-humans so closely associated with us, the interrelating of human and non-human is profoundly intimate. Not only may the behaviour of each be finely tuned, but there are almost certainly what Haraway (2003) has called 'potent transfections'—literal transfer of DNA between the two. Together, dog-and-human (say) or horse-and-rider constitute a different entity, which is deeply enmeshed in complex social and technological networks and their practices (Haraway, 2003; Birke and Michael, 1997). The arbitrary allocation into social/cultural (human) and biological (non-human) makes little sense in the light of such transfections. Yet even in the apparent abstraction of the laboratory (or, more precisely, the animal house serving the laboratory), both rat and humans must learn to live in their highly specialized, but co-created, world. While less familiar, it too involves a choreography, dancing to the tunes of experimental protocols. Sometimes it involves quite deliberate 'potent transfections',[16] if the rat is injected with some human disease. But what we would emphasize here is the co-creation of rat and humans, through their daily intra-actions, to *produce* the practices of science.

So, for many animals, they must learn to participate in a conjoint world, to work with and to recreate it, just as the human must learn to participate in the same conjoint world. Both engage in repeated acts within regulatory frameworks (whether these be relatively local, such as Kennel Club rules, or more general, such as legal—cultural frameworks structuring how humans keep animals). 'Animals' emerges not as a pre-existing category but as something produced by these conjoint actions, and given particular power within the set of actions we call science.

IMPLICATIONS: PERFORMATIVITY ACROSS THE DISCIPLINARY DIVIDE

There are two steps in our discussion of performativity. The first, through analysing how we animal the animals, attempts to bring non-humans out of the categories of 'biological', 'automata', or 'alien essences' and to make the human/non-human boundary more permeable. This draws on several studies which have looked at animal representations in, say, scientific practice. The second step, however, moves us beyond representation, by taking a closer look at the participation of the animal actors, and focusing on the performativity of the two participants in relationship to create something that transcends both—a higher order phenomenon.[17] Thus, there are three kinds of performativity here—of animality, of humannness, *and of the relationship between the two.*

In this final section, we outline some of the ways in which these considerations might usefully cut across disciplinary divides. In particular, we suggest that feminist theory could benefit from a more sustained analysis of 'animality' and how humans and animals mutually engage; likewise, studies of the human/animal relationship could also benefit from feminist scholars' interrogation of gender and its performativity. In turn, we also ask about how these questions generate some further implications for thinking about performativity.

Why does thinking about human/animal performativity matter to feminist science studies, or human/animal studies? One of the ways in which animal studies may influence feminist theory crucially is by offering a productive site for elaborating the burning question of the agency of matter and biological bodies. Much feminist theorizing has emphasized the ways in which bodies matter. In the last decade a growing number of feminist theoreticians (e.g., Haraway, 1991; Butler, 1993; Grosz, 1994; Braidotti, 2002) have addressed the question and tried to shift the perspective from looking at the body as a mere passive recipient of social inscriptions to an outlook which sees the body as an active agent co-acting or intra-acting with social inscriptions. We suggest that a focus on animals can add new productive dimensions to these discussions, so posing the question of the agency of matter in complex new ways.

Animal studies may thus make up a productive site for examining the agency of matter, but avoiding some of the pitfalls. When we, for example, talk about the agency of matter in the shape of human bodies, it is easy to slip back into a discussion of human subjectivity as though it is not embodied. And when we consider the agency of machines and non-organic matter, it is also easy to short-circuit the discussion back into mere human instrumentation or orchestration of machinic performance, once again setting the human subject as the prime mover.

Contrary to both human bodies and machines, however, animals are less easily discarded as subjects in their own right. They are, on the one hand, defined as non-human matter in anthropocentric Western philosophy. But on the other hand, even hard-core instrumentalizing behaviourism or sociobiology is adapting to new understandings of animal cognition, so that non-humans are now less often reduced to the status of controlled robots.

Debates from feminist theory can also aid work on the human/animal relationship. We noted earlier, for instance, how a consideration of human/non-human dyads (rather than on humans or non-humans) might provide a fresh focus, from which to evaluate how borders might be transgressed, and how conjoined agency might operate. Consider, too, Barad's use of performativity to break through the persistent dichotomy between language/representation and the material that is represented. Matter, she proposes, is not a fixed substance, but a doing; that is, matter—the concern of science—must be understood as jointly emerging from material and discursive factors (Barad, 2003).

Thinking about how we think about animals is useful here, as animals both are the material stuff which (biological) science studies and have an (increasingly recognized) subjectivity. If 'dogness', say, is a material *and* discursive product, then we have to understand that in its relationality and performativity. We cannot hope to understand it by selectively focusing on the behaviour of dogs as though they were domesticated wolves, to be studied 'objectively' through science. The problem here is that, at the moment, science is not very good at understanding relationality. Anecdotes abound and data are few (though, as Bekoff points out, we should heed these stories, for the plural of anecdotes is data: Bekoff, 2002: 47). Rather than pursuing an illusory objectivity, scientific studies of animals and of human/animal relationships might usefully borrow from feminist theory, and focus instead on the *performance* of human-plus-non-human—where the constituting discursive practices must be understood to include the material, participating non-human.

While advocating performativity as a useful tool in aiding our thinking about humans and animals, however, there are two dangers. The first is that 'performativity' may be seen only as a product of the individual's engagement with her social world. What we would emphasize here, however, is the need to focus also on *relationships,* which may themselves generate their own performativities; that is, as we noted before, performativity can be thought about in three ways—the human, the animal, and the conjoint hybrid (however that is constituted).

Second, we have written about performativity in a way that suggests that the relationship of human to non-human creates an emerging order. Indeed—but it can also generate disorder, the unravelling of social predictability. Michael (2004) discusses how the 'interruptions' of non-human animals can completely alter sociological research interviews (and everyday social encounters). At times, these 'interruptions' may be construed as 'misbehaviour' on the part of the animal, by either the interviewee or the researcher. In this case, the engagement of the animal is disrupting the creation of social data in ways likely to reinforce its own categorization into 'animality'. Both humans and non-humans, argues Michael, act together to produce both order and disorder in their joint social worlds.

CONCLUSIONS

Thinking about human relationships to animals raises crucial questions not only for feminism but for science studies in general. Animals, after all, are part of what scientists study. Like gender performativity, the processes of human/animal relating constitute discursive practices which *create* animality—and which reproduce relations of power. For in the case of those animals closest to us, it is those behaviours with which we can interact easily which will be reproduced: we humans do not wish to live too closely with the ferocity of savage nature. This is evident if we think about the development of companion animals and their socialization into humanly acceptable forms of behaviour. It is even more evident in the case of laboratory rodents, transformed by breeding programmes into placid bearers of data.

As we implied earlier, biology emphasizes both our similarity and dissimilarity to non-human animals. Similarity is assumed whenever scientists use animals in laboratories as physiological stand-ins, for instance as 'rat models' for some human disease. It is assumed whenever biologists speculate on the evolutionary origins of particular human traits. But there are also sets of practices and performativities, both human and non-human, which reproduce 'the animal' as something apart, as different. Understanding how those work is central to understanding science, and the way that its discursive practices themselves create the species differences that science studies. Indeed, we might even say that the very use of non-human animals in laboratory science *enacts* a radical discontinuity between non-human and human. Using concepts of performativity can, we argue, help us to challenge that separation of non-humans from humans; both human and animal can conjointly be engaged in reconfiguring the world, as Barad (2003) notes. We are all matter, and we all matter.

Feminism needs, we suggest, to analyse further the processes whereby these differences are created, particularly through the authoritative voices of science. We need to understand more about 'animality'—and hence, 'humanness'—and how that cuts across gender. But that must be done in ways that allow for animal agency, participation, and performativity—whether they are stag beetles, laboratory rodents, or companions by the feminist fireside.

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NOTES

1. Barad (2003: 815) substitutes the notion of 'interaction' with 'intra-action' in order to stress that the actors in a performative relationship should not be seen as distinct entities, acting upon each other from 'outside', but as intertwined agencies which mutually construct each other. We will follow this practice in the article.
2. This is an ongoing project; we first presented work on this, using examples from insects in natural history documentaries, and laboratory rats, at a meeting of the Society for Literature and Science, at Aarhus, Denmark, 2002 (and see Lykke

and Bryld, 2003; Birke, 2003). The role of insect actors and visual technologies in the production of popular film documentaries is a particular focus of this work, as well as examples from ethology.

3. Throughout this paper, we use the term 'animal' to denote non-human animal species, unless otherwise specified. The word 'animal' carries many layers of meanings, and can certainly include humans (as in the biological classification of the animal kingdom). However, we chose to follow common colloquial use of 'animal' as not human, precisely to explore the issues raised by cultural separation of non-human animals from humans—particularly in science. Note that 'animal' here is profoundly homogenizing, as though each kind of animal is the same, instead of profoundly different. They are only the same in the effect of the word 'animal' as counterpoint to 'human'—itself not a straightforward term. Midgley (1978) explores the significance of that opposition in Western culture in her aptly named Beast and Man. Later in the paper we address the more inclusive sense of animal/human, which sits more easily with the notion of performativity.
4. See for example Birke and Michael (1997) who discuss such cultural hybrids and their constitution through intervening technologies (such as dog leads). Also see Michael (2004).
5. Thus, the legislation governing animal use in scientific research in the UK covers all vertebrates and now includes cephalopod molluscs (squid and octopus), while in the US some animals (including rats and mice) are excluded from the definition of animal for the purposes of the legislation.
6. One of us (LB) disagrees with Crist in that early ethology did still bear traces of the natural history heritage. The externalist imperative was, however, true by the late 1960s, and part of LB's training in ethology then emphasized the need to avoid at all costs anthropomorphism (see Kennedy, 1992).
7. We explore this further in relation to the behaviour of insects in natural history documentaries; see Lykke and Bryld (2003).
8. With one or two exceptions, such as Barnett's study of the rat, which partly employs an internalist style (Barnett, 2001).
9. Such terminology implies that tools are passive objects; but, as Barad emphasizes, tools and apparatuses are themselves part of the meaning-making of science and as such should be thought of as having agency. Our point here is to stress how often animals are referred to as 'tools' in scientific literature.
10. Nearly forty years ago, one commentator noted that the white lab rat is ' . . . so entrenched in its cozy new habitat that it has influential members of the host species emotionally committed to its continued welfare' (Lockard, 1968). Although we have not drawn explicitly on actor network theory here, this enrolment of welfare-minded people by lab rats is an example of how networks are created between humans and non-humans (animals or technological artefacts: see Callon and Law, 1982; Philo and Wilbert, 2000).
11. See note 6, above.
12. Darwin was quite prepared, for instance, to write about the emotions of animals, and to quote from single examples in ways that would probably not be acceptable today.
13. Crowell-Davis (1992) notes the lack of studies of human/horse interaction, and effects of humans on horses, despite the clear benefits such research might bring to the performance of horses in competitions. That lack remains true ten years later.
14. If there is such a thing as the original wild horse: even the indigenous Przewalski's horse has had to be reintroduced into Mongolia.
15. Anecdotes abound in the world of riding for the disabled of horses apparently helping to keep disabled children on their backs.
16. It is ironic that for some experimental purposes colonies of lab animals have to be protected from human-borne disease by living their lives behind barriers. Potent transfections indeed.
17. Fausto-Sterling (2003) notes how discussion of Butler's notion of performativity of gender could usefully be extended to how non-human animal gender develops, rather than the widespread assumption that gender in non-humans emerges out of some genetic blueprint. She draws on Developmental Systems Theory (also see papers in Oyama et al., 2001), which insists on understanding how organisms develop as systems of processes; genes and environment are part of these systems but cannot be separated out. Together, they create something emergent, or higher order—the form of the organism. Even the gender of the humble laboratory rat cannot simply be attributed to genes, as the mother's behaviour toward her offspring (among other things) influences gender-related behaviour.

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CHAPTER 30

Sex Genes: A Critical Sociomaterial Approach to the Politics and Molecular Genetics of Sex Determination

Joan H. Fujimura

How should the social sciences engage with the materiality of "nature"? The literatures of both the social studies of science and gender studies have wrestled with this question in their analyses of the production of scientific knowledge. In examining the production or consumption of scientific knowledge, these literatures have demonstrated how production and consumption are social and cultural activities. Within this shared terrain, however, many differences emerge both within and between these two literatures on the questions of how to theorize about the social in the scientific and about the scientific in the social, and how to create a language that does not separate science from society.

One topic explored has been the biological explanations for differences between males and females. Biologists and social scientists have proposed explanations for behavioral differences, and debates abound. In this article I do not discuss theories of or data on behavioral differences. Instead, I explore research on the material production of males and females in molecular genetic research on sex determination.

I address the question of how the social sciences should engage with the materiality of nature—in this case, the molecular genetics of sex determination. I employ a critical sociomaterial approach to social scientific engagements with the biological sciences. The sociomaterial approach encompasses the poststructuralist view that meanings are not inherent in events, phenomena, and things. That is, it assumes that humans attribute meanings to things through complex interactions based within specific locations in society, culture, and history. For example, the meanings attributed to nature—how nature is read—differ depending on its reader's location in time and place (see, e.g., Williams 1985; Strathern 1992). This approach also builds on feminist and sociocultural studies of science that have argued against the neat divide between nature (as nature in the raw) and culture (as social discourses and meanings). To emphasize this coproduction of nature and culture, Donna Haraway uses the term "material-semiotic practices" (1991, 208) to refer to the production process and "natureculture" (2003, 1) to refer to its product.

Despite this poststructural understanding of the mediation of nature-culture, a material world does at times assert itself in ways that make us take notice (Haraway 1991; Fausto-Sterling 2000). Some anthropologists have used the term *biophysicality* (Goodman and Leatherman 1998; Escobar 1999) to describe such occurrences, while sociologists of science Bruno Latour (2000) and Michel Callon (1986) refer to the material world as comprised of nonhuman actants and treat them as ontologically on par with human actants.

Given that interventions by the material or biophysical world are acknowledged, the question arises: how does one recognize and deal with the actions of biophysicalities (or nonhuman actants) if they are always mediated by culture? To address this question, I use a critical sociomaterial approach to show how the materiality of sex is produced. I reexamine experimental research investigating the "*SRY*" and "*DAX-1*" genes, the so-called sex-determining genes, in mice and humans.[1]

A critical sociomaterial approach allows the examination and reanalysis of the social and historical production of material knowledge. It assumes that what is taken to be material must be investigated and should not be accepted at face value. It also requires multiple readings of the same data from different sociocultural perspectives or frames of reference. This approach builds on the theoretical efforts of, among others, feminist theorist Haraway (1991), anthropologist Arturo Escobar (1999), philosopher Sandra Harding (1998, 2001), and the practical efforts of social movements around the globe to incorporate perspectives of actors not usually included in the production of science. These varied perspectives produce new knowledge and add dimensions to what Western science calls nature.

Thus, my reanalysis of "*SRY*" and "*DAX-1*" experiments is made in the context of multiple perspectives on sex. I examine human actions in sex determination by analyzing the research methods and interpretations of geneticists as well as the efforts of sex-gender theorists and transgender activists to theorize and remake sex. By analyzing the genetic experiments using multiple perspectives, I provide an alternative reading of the materiality of sex. That is, this reexamination of research on molecular genetic developmental processes provides a focus on the complex sets and pathways of events that produce material sex. These multiple pathways and multiple experimental outcomes could explain variations in human physiological phenotypes that sometimes do not fit neatly into the binary sex categories, male and female. Just as previous studies of human behavior, physiology, endocrinology, and chromosomes have met with difficulties in finally elucidating the source of male-female sex differences, so too have recent attempts to ascertain sex differences at the level of genes met with complexities and ambiguities. My reanalysis of genetic research further substantiates previous knowledge of sex as diverse and variable.

I also find that human and molecular geneticists used their own sociohistorically located normative definitions of sex in their experimental designs and analytic frames, thereby setting the stage for reproducing their own taken-for-granted categories of sex. Yet, even under those conditions, the material world intervened. New molecular genetic technologies produced new data that could have led researchers to new insights about sex development. However, new signals read through old frames can be discounted: in their conclusions researchers decided to ignore data that contradicted their initial assumptions.

This study refers to such ignored data as an "awkward surplus." Here, a critical sociomaterial reexamination of the awkward surplus suggests a different research conclusion from that reported by the scientists. This approach attends to unanticipated research results that experimenters recognized as problematic or awkward and that they thus ignored in their final conclusions. This critical sociomaterial approach provides a way to reexamine unexpected experimental data using different frames of reference and data from other sources. For example, social scientists, using knowledge of social movements (feminism, gay and lesbian movements, queer theory, intersexual and transsexual activism) and social and cultural theory, literally can see differently when examining the work of geneticists and other scientists in the production of the science of sex. Further, the concept of awkward surplus provides science studies with a way of talking about materiality that does not deny human mediation but also acknowledges material agency. More generally, reexaminations of experimental material provide opportunities for natural scientists, social scientists, and other parties to approach research differently and collaboratively to produce new explanations.

THEORETICAL AND HISTORICAL FRAMES OF THE SEX-GENDER DISTINCTION

The sex-gender distinction has been the foundation of gender theory since the 1970s.[2] In their attempts to decouple biology from behavioral differences between the sexes, feminists in the 1970s and 1980s embraced the term *gender* to argue that behavioral differences between girls and boys and women and men were gendered.[3] That is, these differences were constructed within specific cultural and historical contexts (Scott 1988) and through specific technologies (see, e.g., de Lauretis 1987; Lorber 1994). Gendered differences, it was noted, are not uniform but situationally produced and interactionally accomplished (see, e.g., Kessler and McKenna 1985; West and Zimmerman 2002).[4] The term *gender* was also used to speak about sexuality in ways that did not assume or enforce heterosexuality (Rubin 1975). In this period, then, gender became socially constructed, while sex remained in the realm of nature and was left to biologists.

In the 1980s and 1990s, some feminists began to challenge this culture-nature division. Some studied the effect of hierarchies of power on the production of biological models of the body (e.g., Fausto-Sterling 1985; Hubbard 1990; Bordo 1993) and battled biological determinism by arguing that biological knowledge itself was gendered. Critics of gendered and raced knowledges argued that humans attribute meanings to nature through complex interactions based within specific locations in society, culture, and history—that nature is read differently depending, among other things, on the differential positions of its oh-so-human readers.[5]

The 1980s and 1990s also saw more explicit challenges to the feminist embrace of the sex-gender, qua nature-society, split. Historian of science Evelyn Fox Keller (1987), for example, argued against the dualities of sex and gender and of nature and science. Such dualities, she maintained, gave gender unlimited cultural plasticity and made science a set of relativist, interested constructions. In place of these polarities, Keller proposed that a multiplicity of differences could produce varied ways of doing science, each of which could be legitimate. Differences do not have to be reduced to those between male and female, where males and females produce diametrically opposed kinds of science. Nor must one choose universalism as the polar alternative and the only legitimate science. Instead, Keller suggested that there are many different possible kinds of sciences. Feminist theorist and historian Haraway (1988) similarly argued for “situated knowledges” produced by those with particular stakes in those knowledges.

Other feminist writers deconstructed the production of sex. Philosopher Judith Butler (1993) argued that it was incumbent on feminists to show how sex itself is discursively produced under historically located regulatory regimes of gender. Haraway argued more broadly that "bodies . . . are not born; they are made. . . . The various contending biological bodies emerge at the intersection of biological research, writing, and publishing; medical and other business practices; cultural productions of all kinds, including available metaphors and narratives; and technology" (1991, 208). Anne Fausto-Sterling (2000) presented concrete examples of the discursive production of bodies—specifically bones, brains, hormones, and genitalia—by medical and biological professionals.[6] Noting the conflation of the terms *sex* and *gender* in popular discourse, Joan Wallach Scott argued that "the conflation in ordinary usage of sex and gender can be considered a correction of the 'mistake' that treats sex and nature as transparent entities outside of 'culture'; instead, both gender and sex have to be understood as complexly related systems of knowledge" (1999, 72).[7]

In this article I take up the challenge of Keller, Butler, Haraway, Scott, and Fausto-Sterling. I show how the materiality of sex is produced in genetic sex-determination research, and I propose alternative knowledge practices and outcomes. A study of the production of the materiality of sex requires more than an examination of the shaping of sex via gendered understandings of scientists; it requires more than a study of the perception of sex in the minds of humans. Both have been necessary but are not sufficient. The study of the production of the materiality of sex also requires the engagement of social scientists in the production of biological sex. It requires our being in on the design and not just in quality control. I propose, then, that feminists and social scientists go beyond simply accepting or critiquing the products of science to engaging in the actual production of science. I begin by exploring molecular genetics research on sex-determination genes.

DO GENES DETERMINE SEX? ANALYSIS OF RESEARCH ON THE MOLECULAR GENETICS OF SEX DETERMINATION

If social scientists are to engage scientific research, it is incumbent on us to understand the sociotechnical processes that generate knowledge. Scientific knowledge is the outcome of socially situated production, where the social and technical are one process. Social scientific analysis of scientific research requires attending to all aspects of scientific knowledge production, including the daily laboratory practices that produce data and conclusions, the production of scientific articles, the media's selective reporting of some research results and not others, and the interested audiences and consumers of the knowledge produced (who are ever present throughout the production process, not simply at the last step). My investigations included all four aspects, but here I present the experiments that produced genetic knowledge about sex determination. I include the uncertainties, ambiguities, guesses, assumptions, omissions, and exclusions that were part of that knowledge production.[8]

OF MICE AND MEN: THE DESIGN OF MALE SEX-DETERMINATION GENETIC EXPERIMENTS

The search for the male-determining gene began in the 1980s in David Page's laboratory at the Whitehead Institute for Biomedical Research, which is affiliated with the Massachusetts Institute of Technology. Page's laboratory produced a "male gene" that was first named the *ZFY,* or zinc finger Y, and later renamed the *TDF,* for "testis-determining factor" (Page et al. 1987, 1091).[9]

Page and his colleagues' experiments on what they thought might be the testis-determining gene are significant because they set the research protocol for all subsequent studies of male- and female-determining genes. This protocol first studies someone who has been selected for study after having presented him or herself to physicians because of a problem. In this case, Page and colleagues identify these individuals as "sex-reversed" because of their "abnormal" (1091) chromosomal constitutions, where their "sexual identities [are] at odds with their chromosomal makeup" (Roberts 1988, 21). Researchers then develop transgenic animal models of these "variations from the norm" (Roberts 1988, 21) and use them to study and describe the "normal" developmental pathway.[10]

Researchers in Page's laboratory used DNA from XX male human patients (or males with two X chromosomes instead of the usual XY chromosomes) and a female with a chromosomal constitution of "46, X, t (Y, 22) (p11.2; q110)" (Page et al. 1987, 1094), which Page states represents a "reciprocal translocation between Y and autosome 22" (1094). According to David Baltimore, then director of the Whitehead Institute, "This is a classic use of very rare human genetic *defects* to find something very important about biology" (quoted in Roberts 1988, 21; emphasis added). Page states, "The key to the whole endeavor rests with certain exceptions to the rule that Y is sex-determining. . . . XX males were the most important exception" (quoted in Roberts 1988, 21). Leslie Roberts, a writer for *Science,* goes on to say that "XX males appear entirely normal . . . until they try to have children and are found to be sterile. Page reasoned that these men [with XX chromosomes] must contain a piece of Y chromosome, attached to one of their X chromosomes, that does not show up under light microscopy" (1988, 21).

The next step was to attempt to confirm the *ZFY*'s properties in mouse experiments. This did not go well. In December 1989, a team of scientists working at the Medical Research Council National Institute for Medical Research and the Imperial Cancer Research Fund in London announced that *Zfy* (the mouse gene) did not produce testes in mice (Palmer et al. 1989; Kolata 1990). The hunt was on again to find the male-determining gene.

THE MALENESS GENE FOUND

In July 1990 and May 1991, Peter Koopman, Peter Goodfellow, Robin Lovell-Badge, and their colleagues made a big splash with news of a new candidate, *Sry,* for the male-determining gene. They published their male gene research results in the journal *Nature.* Their approach to studying the male gene was similar to Page's: select sterile human males with XX chromosomes, find a gene common to them, then develop a transgenic mouse model to confirm (or contest) that that gene is involved in producing testes. A 1991 article titled "Male Development of Chromosomally Female Mice Transgenic for *Sry*" (Koopman et al.) announced that their *Sry* gene in the mouse model could turn XX female mice embryos into males.[11]

A close reading of the 1991 article by Koopman and his colleagues, however, tells a more ambiguous story. In the first experiment of the study, a number of fertilized eggs were injected with the *Sry* DNA sequences. The eggs were then transferred to the uteruses of female mice to develop, and this produced 158 viable embryos. Eight of these turned out to be XX mouse embryos with *Sry* incorporated into their DNA. Six of these eight were called female and two male.

In the second experiment, fertilized eggs were again injected with *Sry* DNA sequences, and the resulting embryos were transferred to the uteruses of female mice to develop. Ninety-three animals grew to term. Of these ninety-three, three were transgenic XX mice that had incorporated the *Sry* gene into at least one of their X chromosomes. Of the three *Sry* transgenic XX mice, two were females that produced viable eggs and reproduced. The third was called an XX male. It produced no sperm and was infertile.[12] The term *male* was applied because the animal had testes, although the testes were only 22 percent the size of normal male mouse testes. Human geneticist Giovanna Camerino, when commenting on this experiment, said, "Size doesn't matter. What is important is that [the mouse] acted as a male when put in a cage with female mice."[13] That is, the transgenic mouse tried to mate with the females. This single transgenic male intermouse (my term) was the pride of Koopman and colleagues' experiment, and its photograph was displayed on the front covers of *Nature, Science,* and the *New Scientist* and on the front pages of the *New York Times* and the *Boston Globe.*

To summarize the two experiments by Koopman and colleagues: In the first experiment there were three times as many XX females carrying *Sry* (six) as XX males carrying *Sry* (two). In the second experiment, there were twice as many XX females carrying *Sry* (two) as XX males carrying *Sry* (one). The *Sry* gene appeared to produce many more females than males, but still the gene became the poster "boy" of male-determining genetics.

Interestingly, the Koopman and colleagues (1991) article frequently referred to this fabricated *Sry* XX mouse as "normal." That is, the mouse exhibited "normal" size and weight, "normal" copulatory behavior (i.e., "he" copulated with females four times in six days), "normal" populations of Leydig cells, a "normal" reproductive tract (even though it did not produce sperm), and "normal" production of anti-Müllerian hormones and testosterone.[14]

More interesting, though, are the *Sry* females produced in the experiment by Koopman and his colleagues. Like the male mouse, the genome of these mice had also incorporated the *Sry* gene, and yet they displayed female physical characteristics. However, Koopman and colleagues treated these cases as anomalies that did not complicate the finding that *Sry* produces males:

> A further two XX transgenics, m32.10 and m33.2, showed an external female phenotype, yet both carried many copies of *Sry.* These mice have produced offspring and so have functional reproductive tracts and ovaries. They also provide further evidence, along with the transgenic XX female fetuses, that f 741 [*Sry*] does not always cause sex reversal. Although there could be subtle rearrangements of the *Sry* gene making it nonfunctional, the possibility of this occurring in all these cases is remote. There are two more probable explanations. First, these females could be mosaic for the transgene, with only a small proportion of the cells making up the somatic portion of the genital ridge carrying functional *Sry* gene copies. Analysis of XX !-1 XY chimaeras suggests that females or hermaphrodites develop if less than about 30% of cells are XY. Secondly, the expression of the transgene could be affected by the position at which it integrates. Except for a few cases where locus-controlling regions are present, expression of transgenes almost always depends on their chromosomal location. These two alternatives can be examined by breeding from the adult XX transgenic females. Mouse m33.2 has not yet produced transgenic offspring. However, m32.10 has transmitted the transgene to female offspring, suggesting that it is not mosaic. (Koopman et al. 1991, 120)

In other words, Koopman and colleagues offer two explanations for the occurrence of *Sry* female mice. The first argues that the mice might be mosaics—mice that have incorporated *Sry* into some cells (perhaps less than 30 percent) but not into others. However, not only is one mouse (m32.10) a fertile and probably nonmosaic *Sry* female; she also initiated a new and genetically unique strain of mice that produce *Sry* females (Koopman et al. 1991, 120). This means that she incorporated *Sry* into her germ cells and passed on the *Sry* gene to her offspring. If *Sry* is the male-determining gene, how then can a reproductive female mouse carrying *Sry* in her cells still be a female? Here Koopman and colleagues pose a second explanation—that this particular *Sry* mouse is female rather than male because *Sry* is integrated in a position along the X chromosome that somehow prevents it from being expressed. This conjecture requires further research, since Koopman and colleagues could provide no evidence to support it.

It is not unusual for scientific experiments to raise more questions than they answer. Indeed, it is the norm. Why, then, did the article by Koopman and colleagues begin and conclude with the bold statement that *Sry* is sufficient to produce maleness? "It is now shown that *Sry* on a 14-kilobase genomic DNA fragment is sufficient to induce testis differentiation and subsequent male development when introduced into chromosomally female mouse embryos" (Koopman et al. 1991, 117).

Analyzing studies of genetic sex determination allows us to highlight the interpretations made by scientists in the process of experimentation. The experiments by Koopman and colleagues produced one XX-*Sry* sterile mouse with 22 percent–size testes (classified male) and three female-classified XX-*Sry* mice, one of which reproduced other females carrying the *Sry* gene. Although *Sry* researchers noted that these different outcomes of the same gene did not fit with their original hypotheses, they still interpreted their results as confirming their initial hypothesis that *Sry* was the male-determining gene.

Examining the details of Koopman and colleagues' (1991) article also provides an opportunity to make other interpretations. One could, for example, raise an alternative plausible explanation for the experiments' complicated results: that is, that the presence of *Sry* females is evidence that genetic sex determination is more complex than the researchers claimed and that it involves interaction between many genes as well as other possible factors (e.g., ribonucleic acid, mitochondrial DNA, particular proteins in the area, or other epigenetic elements and events).[15] If these females have the *Sry* gene, could there be other genes or other factors that might be guiding the embryo toward femaleness? What is maleness; what is femaleness? Do genes determine sex? Or are things more complicated?

OF MICE AND WOMEN: FEMALE SEX-DETERMINATION GENETIC STUDIES

The dominant scientific view of sex determination from earlier in the twentieth century was that an embryo is female until something triggers a change that leads to the development of male testes (Jost 1953). As many feminist writers have pointed out, the development of females appears to be discussed by biological and medical texts in terms of passivity—in the absence of an active trigger required to induce male development, an embryo develops ovaries, a female secondary sexual characteristic (see, e.g., Martin 1991; Fausto-Sterling 1993a).[16] Early *Sry*/*SRY* experiments were based on this same assumption: embryos develop into female organisms if they lack the *Sry* gene to trigger the onset of male secondary sexual characteristics. Testes and ovaries distinguish males from females in this experimental world of human and molecular genetics. However, experiments in the 1990s countered this truism by presenting evidence for a separate gene involved in female sex determination.

In August 1994, Barbara Bardoni, working in Camerino's laboratory, and her collaborators reported finding a gene region on the X chromosome in the *DSS* (dosage sensitive sex reversal) region two doses of which are powerful enough to disrupt normal testis development in the presence of "SRY" (Bardoni et al. 1994, 500).[17] In an article titled "A Dosage Sensitive Locus at Chromosome Xp21 Is Involved in Male to Female Sex Reversal," published in the science journal *Nature Genetics,* Bardoni, Camerino, McCabe, and their colleagues propose a female-determining sex gene that operates at about the same time in the development of the embryo as the *SRY* gene. The embryo, they argue, is destined to become a male unless a gene in the *DSS* region counters the effect of *SRY:* "A group of four [human] patients found to have a working *SRY* gene nonetheless exhibited varying degrees of feminization, an event that should not happen if the maleness gene were the dominant determinant of gender. Three of the four displayed feminine external genitals, while the fourth had ambiguous genitals. All had been raised as girls" (Bardoni et al. 1994, 497). In these cases, a section of the X chromosome was doubled, giving them a double dose of the *DSS* gene. Two copies of a gene in the *DSS* region of the X chromosome can help push the fetal gonads, which have the potential to become either ovaries or testes, to become ovaries. Thus, an extra dose of the gene in males would undermine the efforts of the *SRY* factor to build testes. In a follow-up study (Swain et al. 1996), Camerino and colleagues proposed that a gene in the *DSS* region called "*DAX-1*" was responsible for undermining the "*SRY*" gene's action.

OF MICE, HUMANS, LEAKINESS, AND COMPLEXITY

Researchers at Larry Jameson's laboratory at Northwestern University (e.g., Yu et al. 1998) subsequently conducted studies on *Dax-1* from which they argued that *Dax-1* is not a female-determining gene. Jameson and his colleagues reported that disabling the *Dax-1* gene in female mouse embryos did not prevent these embryos from developing into mice with ovaries. Moreover, they reported that male mouse embryos with disabled *Dax-1* genes became sterile. Their conclusion was that "*DAX-1*" is not an ovary-determining gene but rather has a critical role in spermatogenesis, the generation of sperm.

Camerino accepts the Jameson laboratory's claims for its mouse model but not for humans. She believes that species differ in their genetics of sex determination. *Sry*/*SRY,* she argues, acts very differently in mouse and man in the timing of the expression of the gene. Camerino further contends that interactions between human *SRY* and *DAX-1* also differ from those between mouse *Sry* and *Dax-1.* Subsequent studies have shown that sex-determination genetics also differ between organisms in different phyla, thus reinforcing Camerino's position on mouse-human differences (Goodfellow and Camerino 1999).

Camerino's late 1990s studies have pointed to the vital role of *DAX-1* in sex determination in humans. In 1999, after Camerino's research on *DAX-1* raised questions about *SRY*'s power to transform embryos, Koopman (1999) hypothesized that the embryo did not develop into a male because the *Sry* mouse gene may be just one trigger in a series of steps that transform the XX embryo into a male mouse. Other possible explanations were that "*SRY* may act to repress genes that activate the female pathway of development, or to repress the repressor of the male pathway" (Koopman 1999, 840–41), or that "*DAX-1*" represses "*SRY*'s" action (Goodfellow and Camerino 1999).

Goodfellow and Camerino (1999) propose a hierarchic cascading view of sex determination, where *SRY* and *DAX-1* in humans act as triggers at the top of the hierarchy of a series of genes and activities necessary to the development of sex (here defined as ovaries and testes). Thereafter, many other events occur in the process of the organism's sex determination—for example, other genetic switches turn on or off during the embryo's development. These different genes and their expressions generate subsequent genetic actions, and a cascade of genetic switches and expressions produce the organism's final sex characteristics.

But there are more complications in sex determination and more questions than answers. Some scientists argue for proliferation in genes of promoter regions, structural genes, different forms of proteins from the same gene, and so on that complicate the picture of sex determination (Goodfellow and Camerino 1999). There is a long list of genes that are suspected of being involved in sex determination, and this list gets longer every year. In addition to *SRY* and *DAX-1,* these include *Wilm's tumor 1,* or *WT-1,* whose expressed protein has several different splicing alternatives and produces up to twenty-four different forms of the protein; *SF-1,* which is a nucleohormone receptor that is expressed in the hypothalamus, pituitary, gonads, and adrenals; and *Sox-9,* which is similar to *Sry.*[18] Then there are the interactions among the genes. As Camerino says, "*Everybody has found interaction of everything with everything.* With different results, etc., [sex determination] is complex, and the genetic term is leaky. Leaky. This is a prokaryotic genetics term.[19] It means that things are not that stable. They are not something strongly determined."[20]

Camerino believes that "*DAX-1*" is a female sex-determination gene high up in the hierarchy of sex determination (higher than *Sox-9, SF-1,* etc.) as *SRY* is high up in the hierarchy of sex determination for males (Goodfellow and Camerino 1999). Although this has not yet been demonstrated, she believes that future experiments could prove it to be true. In the meantime, Camerino calls "*DAX-1*" an antitestis gene because it has been shown that a double dose of it can turn off "*SRY.*" The interactions among all these genes and proteins contribute to the instability, or "leakiness," in sex determination.[21]

What is sex? How is it determined? Does "*SRY*" cause males to develop? Does "*DAX-1*" cause females to develop? Does a cascade of molecular elements and interactions determine sex? At this writing it is thought that "*SRY*" and "*DAX-1*" are key genes that act initially to trigger male or female development in an embryo. However, it is believed that other genes also are needed to continue development toward male or female. These genes interact with one another, and the interactions can lead to other events. One possibility is that they could lead to hermaphroditic combinations of characteristics. Another possibility is that different cells in the same embryo have different genes, which then lead the embryo to develop into a hermaphroditic body. These embryos are called mosaics. At this point, genetic studies point to more complex interactions and unanswered questions rather than to any clear answers. These complex interactions are part of the leakiness of genetics.[22]

DO HUMANS DETERMINE SEX?

In the experimental arena of sex determination, molecular and human geneticists are the arbiters. But do genes and geneticists determine human sex identity? Physicians, psychiatrists, parents, courts, prison officials, and at one time the International Olympics Committee have all taken positions on human sex determination, often with little contest. Recently, social scientists, feminist theorists, queer theorists, and gay rights, intersexual, and transsexual activists have attempted to gain authority in debates about sex determination.

Intersexual Social Movement

The sex-determining gene experiments discussed were based on studies of human patients who exhibited genitalia and reproductive organs that did not fit neatly into standard categories of male and female. Often classified as intersexuals, people with sexually indeterminate bodies have become both subjects and objects of research and activism in the last ten years. Medical and research professionals have often treated intersexuals as residuals—people whose bodies do not fit commonly understood sex categories and need to be managed, explained, or made to fit into one or the other category. Recently, however, intersexuals have begun to organize to contest the medical definitions of their bodies and to work toward building collective identities to differentiate themselves from standard male and female categories and to establish intersexuality as a new and standard category of sex identity.

In the United States, medical practices have been used to manage intersexual infants and to surgically and chemically mold them to fit dimorphic sex categories (Dreger 1995). It has been common for doctors to "fix" sexually ambiguous babies soon after birth by surgically creating either male or female genitalia to accord (when possible) with internal reproductive organs. Sociologist Suzanne J. Kessler (1990) finds that decisions about which sex to assign to an infant were made primarily on the basis of what she calls aesthetic concerns, such as the length of the penis. If doctors guessed that the infant's penis was destined to be too small, then female genitalia were constructed. However, physicians saw their work as merely restoring the person's "natural" sex to him or her and, along with parents, regularly made decisions about these matters with the intention of protecting children from psychological damage. Kessler argues that these physicians displayed a "failure of imagination" (1990, 26) in attributing their decisions to nature: "Rather than admit to their role in perpetuating gender, physicians 'psychologize' the issue by talking about the parents' anxiety and humiliation in being confronted with an anomalous infant" (1990, 25).

Gender reassignment has not necessarily produced happy outcomes in adults, and some have organized themselves into the Intersex Society of North America (ISNA), which is based in San Francisco. In the late 1990s, ISNA member and founder Cheryl Chase and her colleagues generated a social movement to halt surgical practices on infants or at least to insist on more discussion before infants are transformed into one or the other sex. Members of ISNA marched on medical schools to halt sex reassignment surgeries and published newsletters and press releases to educate the public about intersexuality. They have been the subject of *Nova* programs aired by the Public Broadcasting Service and of articles in major newspapers. In an October 14, 1996, press release titled "Intersexed Decry American Genital Mutilation," the ISNA compared intersexual infant surgery to African genital mutilation (see Chase 1996).

Chase and her ISNA colleagues have produced their own versions of naturalist baselines and categories to resist the medical practices that have pathologized and transformed their bodies.

> Intersex specialists are busily snipping and trimming infant genitals to fit the Procrustean bed that is our cultural definition of gender. . . . Surgical and hormonal treatment allows parents and physicians to imagine that they have eliminated the child's intersexuality. Unfortunately, the surgery is immensely destructive of sexual sensation as well as one's sense of bodily integrity. Because the cosmetic result may be good, parents and physicians complacently ignore the child's emotional pain in being forced into a socially acceptable gender. The child's body, once violated by the surgery, is again and again subjected to frequent genital examinations. Many "graduates" of medical intersex corrective programs are chronically

> depressed, wishing vainly for the return of body parts. Suicides are not uncommon. Some former intersexuals become trans-sexual, rejecting their imposed sex. (Chase 1996, 1)

By violating the natural body in their pursuit of a socially normal child, Chase contends, physicians and parents actually produce pathology.

Chase is a major protagonist in *Sexing the Body,* written by feminist biologist Fausto-Sterling (2000). Fausto-Sterling uses contemporary and historical biomedical scientific research on intersexuals and sexology to argue for multiple sex categories. In 1993 she published a provocative op-ed piece in the *New York Times* proposing that humans should have five sex categories rather than two (Fausto-Sterling 1993b). She argues that there is a physical continuity between the sexes of male and female, and rather than make bodies and persons fit into just two categories, male and female, she proposes that additional categories be embraced by medicine and society.[23]

Alice Domurat Dreger, Fausto-Sterling, Kessler, and the ISNA have made a difference. Intersexuals now have more support if they choose to speak out about their physiologies. Physicians do not automatically perform surgery on infants with some conditions, and parents are more involved in deciding whether or not to surgically transform infants with ambiguous genitalia into males or females (see, e.g., Navarro 2004). Nevertheless, two sex categories still dominate the choices and frames for physicians, parents, and scientists.

TRANSSEXUAL ACTIVISM

In their debates about biology and sex identity, many transsexuals insist on dichotomies but not those determined by anatomy or physiology. They argue that their physical bodies are not "natural" and that they instead feel more "naturally" to be members of the sex that does not accord with their genitalia. That which is usually taken as natural, the body, becomes unnatural, while that which is usually assumed to be socioculturally produced, gender, becomes natural. In this way, they argue differently from Chase and others who use bodies and biology to argue against dichotomies. Some transsexuals argue against the male-female dichotomy and for a wide range of gender identities, but they also argue for the naturalism of gender (e.g., Roughgarden 2004). Other feminist writers have argued that body and behavior are not separate entities and instead that materiality and gender identity are codetermined (e.g., Butler 1993). They argue against trying to adjust the body to fit an ideal gendered identity and for the complex and varied possibilities of the body—that is, for a transsexual position that speaks from outside the boundaries of the sex-gender binary.[24] Transsexuals, then, are not homogeneous in their positions regarding sex-gender dichotomies and naturalistic explanations for gender and sex identity. Despite or perhaps because of this heterogeneity, transsexuals contest the simplistic sex-gender, natural-social dichotomies in ways that emphasize the discursive construction of bodies and identities.

ANALYSIS OF DATA AND DISCUSSION

What is sex? Will genetics be the final authority in answering this question? Sex gene experimenters have argued that "*SRY*" is an active element in the development of testes and that "*DAX-1*" is an active element in the development of ovaries. As stated earlier, to explain the ambiguities in *Sry* experimental outcomes on mice, some researchers have argued that in addition to *Sry* a cascade of other genetic and nongenetic factors and interactions are necessary to determine sex. But they do not question the assumption that testes indicate males and ovaries indicate females.[25] In contrast, some intersexual and transsexual activists, feminist theorists, and social scientists have contested this medical definition of sex. Although their definitions of sex are heterogeneous, transsexuals agree among themselves that possessing testes or ovaries does not determine their sex identities. Intersexual activists, biologist Fausto-Sterling, and psychologist Kessler use the existence of phenotypic features like ambiguous genitalia and reproductive organs as evidence that sex is not a male-female dichotomy. Using feminist and social scientific perspectives in light of research on transgender social movements, I now present an analysis of two processes through which sociocultural frames entered into the design of the sex-determination experiments I have presented above, and I examine how these frames influenced the analysis of the resulting data.

EXPERIMENTAL DESIGN: THE NORMAL DEFINES THE PATHOLOGICAL AND THE PATHOLOGICAL DEFINES THE NORMAL

The *Sry* and *Dax-1* mouse experiments show that human and molecular geneticists used their own definitions of what constituted normal sex and pathological sex to design their scientific investigations. Despite their differences, both *Sry* and *Dax-1* researchers set up their initial experiments defining sex as a binary. They built this assumption into their experiments by choosing patients who presented themselves in the clinic with what were considered nonstandard sex phenotypes. In the mid-1980s, Page's laboratory used DNA from XX male human patients who were impotent (Page et al. 1987). Koopman and colleagues (1991) began with sterile male human patients with XX chromosomes whose common gene was used to develop a transgenic mouse model. In the early 1990s, Camerino and her colleagues (Bardoni et al. 1994; Zanaria et al. 1995) used data from female human patients with a "working *SRY* gene who nonetheless exhibited varying degrees of feminization" (Angier 1994, C1). In the language of Camerino and her colleagues, "the double dosage of DSS in individuals with Xp duplications and a functional SRY gene . . . hampers repression of the ovarian pathway, leading to gonadal dysgenesis and phenotypic sex reversal" (Bardoni et al. 1994, 500).

These researchers' choices of patients for their studies set the parameters for their definitions of normal sex to be males or females who can heterosexually reproduce. The researchers would classify any variation from this to be pathological. However, as sociologists and historians have argued, classifications, categories, and taxonomies of scientific and medical knowledge are produced within specific historical situations. Further, categories of normal or healthy and pathological or ill are historically co-constituted categories, defined only in relation to each other (Canguilhem 1978). There is no normal without a pathological and vice versa. Michel Foucault (1970, 1978) argues that such classifications and taxonomies of scientific and medical knowledge constitute a map of the power relations of the particular time period and also have the power to normatively govern the ways humans act and feel.

Biological categories and classifications, then, are not natural, value free, or innocent. Sex categories in particular operate within socially prescribed systems of meaning. Human and molecular geneticists use their own sociohistorically located normative definitions of sex to design their experiments on sex determination. As a result, new molecular genetic experiments on sex determination do not challenge the previously determined socially defined categories. Instead, they give material form to socially defined ideas. By selecting particular human bodies in the design of their sex-determination experiments, these geneticists have reproduced their own taken-for-granted categories of sex.[26]

The genetic experiments I have presented are producing particularistic, not universalistic, knowledge. However, because of the power held by science and medicine in our world, the two sexes—male and female—are once again rendered natural and original, this time through the *Sry* and *Dax-1* mouse experiments. But power is a process that is never finalized. Just as feminists, queer theorists, and transgender activists are attempting to transform definitions of sex, this study challenges this power by showing how human and molecular geneticists insert normative societal assumptions into their scientific practices.

EXPERIMENTAL DATA ANALYSIS: IN SEARCH OF THE MALE-DETERMINING GENE

Sry mouse experiments incorporated yet another set of assumptions: they focused on the male-determining factor rather than on the female. Hypothesizing that a gene common to XX men induces embryos to develop as males, the *Zfy* and *Sry* mouse studies were designed in an attempt to find that gene. The researchers found a version of that gene and inserted it into XX female mice to see if it would transform the females into males. When Koopman and colleagues (1991) produced a mouse with a small penis, they concluded that they had found the male-determining gene. They acknowledged that many more XX embryos had incorporated the *Sry* gene and developed as females rather than males, including one reproducing female that gave birth to female offspring carrying the *Sry* gene. However, in their frame of reference—the focus on male sex determination—the researchers relegated the female *Sry* mice to the status of anomalous data and omitted them from their published conclusions.

The researchers' focus on finding male sex determinants is in line with the history of sex-determination research. As stated earlier, it has been assumed that an embryo is female until something triggers a change, causing the development of male testes (Jost 1953). Thus, sex-determination research has been structured to search for the determination of the male phenotype (Eicher and Washburn 1986). Eva M. Eicher and Linda L. Washburn note that "the genetics of testis determination is easier to study [than ovary determination] because human individuals with a Y chromosome and no testicular tissue, or with no Y chromosome and testicular issue, are relatively easy to identify" (1986, 329).[27] While some experiments have countered the idea of passive female sex development, the idea of active female sex development has not entered easily or consistently into the literature (Fausto-Sterling 2000, 346). The research of Camerino and her colleagues on *DAX-1* joins this minority tradition, although it still represents sex as a binary male-female dichotomy. The field of sex determination is dominated, however, by *Sry* research and continues in the vein of early twentieth-century ideas.

EXAMINING THE AWKWARD SURPLUS FROM NEW FRAMES OF REFERENCE

The *Sry* mouse studies employed new molecular transgenic technologies to investigate the details of sex development in mice. The introduction of these new technologies made new signals possible. These new signals could have led researchers to new insights about sex development. I show, however, that new signals read through old frames are not seen.

One fascinating aspect of empirical scientific research is its ability to surprise researchers with unanticipated results. Although philosopher and historian of science

Thomas Kuhn argues that the paradigmatic frame of normal scientific practice does not aim at novelty and even suppresses it, he also acknowledges that it often yields "pre-novelties" (1962, 5–6) in the form of anomalies. Kuhn also argues that anomalies must be recognized—that is, recognized as new knowledge and not as errors or noise. Kuhn suggests that it is usually not the paradigmatic practitioners who recognize anomalies as novel, but instead it is the new generation of researchers, or even researchers from another field, who can see novelty because they are not immersed in the governing paradigm.

Anomalies can, in Kuhn's schema, lead to the production of both new knowledge and a new paradigmatic order, a new form of normal science. However, in Kuhn's discussion the sources of the differences in perception required to recognize novelty remain within the science community, albeit in a different generation or discipline. Historian of science Nancy Stepan (1993) goes beyond Kuhn to argue that paradigms are not just limited by a scientific community's set of theories and practices but also by social and cultural metaphors. In contrast to Kuhn's intellectualist explanation that a paradigm changes with the accumulation of a critical mass of anomalies that cannot be explained by the paradigmatic frame, Stepan argues that it is often through social, political, or economic changes in society that both scientists and citizens come to see that cultural metaphors have governed how we perceive reality and that they no longer apply.

The data produced by the *Sry* and *Dax-1* mouse experiments, the questions raised about sex/gender by transgender and feminist activists, Kuhn's discussion of anomalies, and Stepan's 1993 revision of Kuhn's ideas together suggest that there may be data that tend to be ignored because they do not fit the frames of reference of their observers. Considering this awkward surplus, I argue that the introduction of new frames of reference may illuminate results of experiments that have been ignored in the investigation's conclusions.[28] In this way, the concept of awkward surplus can aid in the rereading of experimental conclusions and thereby produce alternative interpretations with different social consequences.

Reexaminations of study results such as those presented here provide opportunities for natural scientists, social scientists, and other parties to attempt to work differently and collaboratively to produce new explanations. Using the notion of awkward surplus, social scientists and social activists can fill a role similar to that of scientists from another field, those whom Kuhn sees as potential innovators—people who can see anomalies as sources of novel ideas and findings because they bring different assumptions to the table. With respect to the *Sry* and *Dax-1* studies presented here, I apply my knowledge and skill in understanding social frames of meaning to explore whether, when, where, and how these frames affected the researchers' scientific perception. As Haraway argues in "Situated Knowledges" (1988), other actors with stakes in a problem should be involved in studying it.

In examining *Sry* experimental data, I am attempting to salvage the experimental results that sex gene researchers first acknowledged and then chose to ignore. That is, although the researchers (Koopman et al. 1991) noted that some mice did not perform according to their expectations, they failed to conduct further experiments to try to make sense of these anomalous results. Koopman and colleagues chose instead to continue to construct their follow-up experiments as if *Sry* caused maleness in mice. Their subsequent studies presented additional complexities and ambiguities that the scientists could not explain. One researcher, Camerino, continually referred to some of the results as "bizarre."[29] Although researchers attempted iterations to make the results fit their original assumptions, these subsequent experiments did not answer their questions, and they decided to wait for "better" experiments.[30] *Better,* I argue here, refers to experiments that will yield results that make sense to them within their frames of reference.

After identifying an awkward surplus of results in the data, my next step was to explore new interpretations. By reviewing the data without thinking about sex as a binary category, I saw that the last fifteen years of research on "*SRY* " and "*DAX-1*" have provided much evidence for complexity in the genetics of sex determination. Recent experiments have raised the possibility of a proliferation of genes in promoter regions of the chromosome, of structural genes, and of different forms of proteins being produced by the same gene, all of which complicate the question of sex determination. There is by now a long list of genes suspected of being involved in sex determination, and this list grows longer every year. If we also consider the interactions among these genes, sex determination at the genetic level is steadily increasing in complexity. When we add the interactions of genes with various proteins, developmental pathways, cell signaling pathways, and many other parts of cellular, organismal, and environmental parts and processes that are fast becoming the territory of a new field called "systems biology" (Fujimura 2005), the complexity of sex determination escalates even more.

A key characteristic of complexity is instability. Using a term first developed in the field of prokaryotic genetics, Camerino argues that sex determination is "leaky," by which she means unstable or not strongly determined.[31] That is, there is no single pathway through which sex is genetically determined. Indeed, there may be many pathways with multiple different genes involved in each pathway. And although Camerino believes that there is a hierarchy of pathways with "*SRY* " and "*DAX-1*" involved at the top of the hierarchy, this argument must be verified.

In contrast to the geneticists' view, I suggest that a feminist, social scientific, or transgender analysis might consider the many sex variations as resulting from multiple developmental pathways that involve genetic, protein, hormonal, environmental, and other agents, actions, and interactions. These variations need not be represented as outliers, residuals, anomalies, or pathologies in a binary system. Instead, a reanalysis of *Sry* and *Dax-1* mouse research shows that genetics can produce phenotypic variations suggesting that sex is a fluid concept, not a binary concept incorporating only the conventionally gendered sexes of male and female.

In summary, the concept of awkward surplus is useful, first, to help us attend to unanticipated results that are recognized as problematic or awkward by experimenters and are thus ignored in their conclusions. Second, the concept provides an opportunity to reexamine unexpected experimental results either by using different frames or perspectives or by reexamining them in conjunction with data from other sources. Third, the examination of awkward surpluses provides a space where scientists and social scientists can work together in the production of new knowledge.

WHO ADJUDICATES THE AWKWARD SURPLUS?

In addition to the interpretations of geneticists in the original *Sry* mouse study (Koopman et al. 1991) and my reanalysis, there may be other interpretations. The designation of awkward surplus and possible multiple explanations of what the awkward surplus means raise other epistemological and methodological questions. How do we decide which interpretations are valid? If prescribed systems of meaning frame our very perceptions of matter, is my alternative interpretation not just as situated in particular sociocultural assumptions as those of the biologists I study? With respect to the concept of awkward surplus in particular, how do we adjudicate whether an awkward surplus provides useful or useless information? And who should adjudicate?

Answers to these questions in the social studies of science, medicine, and technology are many and are heatedly debated. Some science studies scholars argue that our job is not to decide what is valid knowledge but to study how each possibility fares in the struggle for scientific authority. These scholars prefer to descriptively analyze scientific practice and struggles for authority without taking normative positions on knowledge outcomes (e.g., Lynch 2001). However, other science studies have also shown that many nonscientists have already intervened in the making of science. Religious groups have asserted their agendas, sometimes supporting the programs of particular scientists (Shapin and Schaffer 1985) and sometimes intervening against the programs of particular scientists through control of research-funding processes of government agencies such as the National Institutes of Health (NIH) and the National Science Foundation (Borenstein 2004). Private industrial concerns have inserted their agendas through their in-house research or through institutional funding of research in private institutes and research universities (Krimsky 2003). Governments have also selectively influenced the development of scientific knowledge in particular directions (MacKenzie 1993; Eden 2003). Beyond these overt exercises of political power in the making of knowledge, social studies of science have demonstrated the introduction of political and cultural agendas into scientific research through subtle and unintentional processes. Indeed, as Stephen Jay Gould (1981), Stepan (1993), and Hall (1976) argue, throughout history it has been difficult to separate scientific efforts from commonly accepted cultural knowledge.

Given the past and present roles of power and partiality in the production of knowledge, feminist scholars of science in particular argue that science analysts should play a part in the struggle for authority by taking positions and supporting some knowledge claims over others. Haraway (1988) argues that those who have the greatest stakes in a knowledge claim should act collectively to produce that knowledge. Harding (1998) has provided epistemological arguments for the production of new kinds of knowledge by participants who are not professional Euro-American scientists. Scientists themselves take heterogeneous positions. Some argue that science should police itself, while others argue that there is a place for nonscientists in scientific knowledge production.

However, the epistemological frames of Haraway (1988) and Harding (1998) still leave us with the questions of who qualifies as a stakeholder in a particular problem and how those stakeholders who are not professional scientists can participate in the making of science. For instance, the Bush administration's conservative religious policy makers and backers argue—and have acted upon the view—that they have a stake in scientific research. They have taken up positions on stem cell research and influenced NIH decisions about which projects to fund.[32] In the case of sex-determining gene research, I argue that intersexuals should have some authority in the making of knowledge of sex. However, the Bush administration could similarly argue that the religious ultraright should also have a place at the table. Is adjudication possible, or is it simply a battle of wills and power? In the battle of power-knowledge (Foucault 1980), barriers to participation are usually high.

The problem of who should and can authorize science is a question that appears to be answerable only historically (e.g., Fujimura 1998). Nevertheless, some science studies scholars are attempting to wrestle with this problem prospectively in epistemological terms and practical terms.[33]

A CRITICAL SOCIOMATERIAL APPROACH

This analysis of sex-determination research demonstrates the critical sociomaterial approach to the study of science, a theoretical approach that incorporates ideas and lessons from feminist theory and the social studies of science. I have included an analysis of science that incorporates the sociocultural frames of reference of researchers who have stakes in and perspectives on a particular scientific problem. I call for social scientific or feminist analyses of science to include an examination of the production of the materiality that supports scientific claims. I propose that feminist social scientists and activists should include the exploration of the materiality of sex in their analyses. The biology of sex is too important to leave to biologists alone because they usually are not trained to attend to and analyze how sociocultural frames influence their own experimental processes. This critique is exactly what feminist, social scientific, and humanist analyses can provide. Their different frames of reference may suggest new interpretations of evidence and even new experimental designs.

The methods for analyzing the material production of science include reading research articles in search of data that could be meaningful in a frame or context of analysis different from that of the original experimenters and/or observing scientists at work producing scientific knowledge in the laboratory or the field and identifying and examining awkward surpluses of data that do not fit within the researchers' frames of reference. This analytical approach requires an epistemological argument for the claims made in the new analysis and a discussion of the proponents' stakes in their role as knowledge makers.

CONCLUSION

I have employed a critical sociomaterial approach to reexamine scientific mouse experiments on sex-determining genes, especially *Sry* and *Dax-1*. I have provided a critique of the investigations and an analysis of some of the investigators' awkward surplus data. This approach to science incorporates theoretical efforts to move beyond reading society onto nature and reading nature onto society. It does not impose sociological categories onto the natural sciences, nor does it impose biological categories onto the social sciences. Instead, it argues for a collaboration that gains from different expertises.

The results of this reexamination demonstrate that the design and analysis of molecular genetic experiments are inhabited by sociocultural meanings and understandings. In the case of genetic sex determination, scientists used the social categories of "normal males" and "normal females" to design their experiments and protocols, and they reproduced these categories in their experimental processes.

My reexamination of research in sex determination also shows an awkward surplus of data that researchers ignored in their conclusions from the *Sry* mouse experiments. They did not view some experimental results as findings because those results did not fit their cultural expectations.

In contrast, from the perspective of feminism and social science as well as of research on transgender movements, I suggest that these residual data provide significant information on the actions of sex genes.

Instead of viewing the results as bizarre, I suggest reinterpreting the residual data to illuminate genetic instability (leakiness) and possible multiple pathways of sex development as explanations for the variations in body phenotypes that do not fit the binary male-female norms. *Sry* and *Dax-1* mouse experimental results that fall outside the experimenters' frames of reference may be legible within other frames. Sex may be highly variable and more fluid than geneticists (and many of the rest of us) anticipate.

I argue for the examination of the awkward surplus in scientific data as a valuable research tool. Reconsideration of data and conclusions would use frames of reference different from those of the original experimenters, frames taken from other actors and realms of life.

The concept of awkward surplus provides science studies with a way of engaging with material agency. Even within the cultural framing of understandings of nature in a particular period, we find biological outcomes that stand clearly outside scientists' abilities to control or explain them. The concept of awkward surplus provides a theoretical and methodological framework for thinking about anomalous results when meaning has not quite become fixed.

Awkward surplus is also useful for thinking about how feminist and other social theorists and activists can participate in creating knowledge about materiality. The work of transgendered activists and some feminist theorists to promote the acceptance of variations in bodies and the normalization of their own bodies can be useful in the production of molecular genetic research. Scientists, too, must have an opportunity to cross the divide. They can use the work of feminists, queer theorists, and transgender activists to think creatively about their own research surplus and their accepted protocols for producing knowledge. The awkward surpluses of scientific data indicate complexities that fall outside the structures of scientific paradigms and some social frames of meaning.

With respect to sex itself, these readings of novel data suggest that the variations in and complexities of sex development raised by feminist analysts at the levels of human behavior, bodies, hormonal systems, embryos, cells, and chromosomes are replicated at the level of genes. Sex, even at the genetic level, is a sociomaterial process and product.

Given this conclusion, my study of the production of the materiality of sex joins arguments in feminist studies for the collapsing of the sex-gender (qua biology-society) distinction. Instead of treating sex as biological and gender as social, I argue that sex, like gender, is a sociomaterial product. Sex-determining gene research and the political actions of transgendered activists introduce moments of ambiguity and transgression that disturb the dichotomies of male-female, sex-gender, and nature-culture. Highlighting the social aspects of sex contests assumptions about gender and sex and thereby about the sex-gender split.

My investigation is an argument for broadening our social imaginaries—our definitions and understandings—of the material, the natural. A critical sociomaterial view of sex integrates sociocultural and historical investigations of the production of the material (e.g., the complexities and variations of sex physiologies and genetics) with diverse social imaginaries about sex and bodies proposed by feminists, queer theorists, intersexuals, and others. In this approach, we study and juxtapose the actions and interactions of social activist groups, social theorists, biologists, bodies, and genes in order to understand the collective, contentious, contradictory, and interactive crafting of sex in humans.

I do not mean to argue that the natural should be the foundation for substantiating, explaining, or changing existing gendered arrangements in society. Social imaginaries should be enough for promoting an acceptance of diversity. Historical examples of efforts to use natural differences to justify social hierarchies provide yet another reason for eschewing biology as foundational for social practices. The recent rise of evolutionary psychology is the latest in such efforts to produce natural arguments for social practices and hierarchies.

Nevertheless, demonstrations of the sociomaterial production of sex, the Möbius strip production of sex, are useful for maintaining our awareness that natural categories are also social categories. Further, even as our current language of analysis maintains the division between the natural and the social, the point of a critical sociomaterial approach is to move in the direction of a language where there is no division, where we are always conscious that the natural and the social are not separated.

For example, we need to think of the categories male and female not as representing stable, fundamental differences but as already and always social categories. They form a set of concepts, a set of social categories of difference to be deployed for particular purposes. Ergo, what counts as male and female must be evaluated in their context of use. The categories male and female, like the categories men and women, may be useful for organizing particular kinds of social investigation or action, but they may also inhibit actions.

A critical sociomaterial approach that joins awkward surpluses from the laboratory with the experiences of people in the world opens up opportunities to challenge the taken-for-granted scientific categories that help to construct or maintain definitions of similarity, difference, and pathology. This is particularly important today, when new biotechnologies are being used to link disease and behavioral genes with particular social categories of race and ethnicity.

NOTES

1. *Sry* stands for sex-determining region Y gene, the gene that sits on the Y chromosome and is currently considered to be the gene that initiates male sex characteristics. *Dax-1* is the name for the dosage-sensitive sex reversal adrenal hypoplasia gene 1, Xp21, a transcription factor involved in adrenal cortex development and gonadotropin secretion. It has been widely accepted as an "antitestis" or ovary-determining gene because patients with a duplication or "double dose" of *Dax-1* had features of XY sex reversal, a condition in which individuals have the chromosomes of males but the physical attributes of females. For the same gene sequence, the agreed-upon notation in research articles is the italicized and lowercase *Sry* or *Dax-1* for the mouse gene, the italicized and capitalized *SRY* or *DAX-1* for the human gene, and the italicized and capitalized with quotation marks "*SRY*" or "*DAX-1*" for the gene in multiple species.
2. This is not intended to be a complete discussion of the history of gender theory, feminism, or gender and science.
3. The term *gender,* as separated from *sex,* originated in John Money and Anke A. Ehrhardt's (1972) studies of hermaphrodites.
4. For work on the idea of gender as process, see, e.g., Ferree, Lorber, and Hess (1999) and Butler (2004).
5. See, e.g., Rose 1983; Smith 1987; Trinh 1987; Haraway 1989; Russett 1989; Schiebinger 1989; Laqueur 1990; Strathern 1992; Glenn 1999; Duster 2003.
6. Historian of science Diana Long Hall's (1976, 92–94) research on sex hormones in endocrinology demonstrates how novel biological practices and technologies in the 1920s changed and disturbed established representations of sex differences. For more recent work on the history of the intersection of hormone research and sex disciplining, see Oudshoorn (1994), Clarke (1998), and Fausto-Sterling (2000, chaps. 6, 7, 8). For an interesting challenge to feminist critiques of sex hormone research, see Roberts (2000).
7. Feminist theorists Moira Gatens (1996) and Elizabeth Grosz (1994) also argue that the early division between sex and gender was useful for its purposes at that time but that this division now serves to keep feminists attending to social gender and to cede their authority over biological sex to biology.
8. Since the 1970s scholars in the social studies of science have explored how scientific knowledge is marked by its situation and process of production.

9. See Fausto-Sterling (1989) for an early critique of Page's research. Again, *Zfy* equals the mouse gene, capitalized *ZFY* the human gene, and "*ZFY*" the gene in multiple species.
10. I use quotes around the term *normal* to refer to the construction of the "normal" through the construction of the "abnormal" developmental pathway. I discuss the simultaneous construction of the normal and the "pathological" later in this article. Transgenic animals or organisms are products of genetic manipulation. Their genetic material (nuclear deoxyribonucleic acid [DNA]) has been altered using recombinant DNA techniques that allow the movement of DNA from one organism into another. These DNA transfers are sometimes from a different species, sometimes from the same species.
11. Again, *Sry* indicates the mouse gene, *SRY* the human gene, "*SRY*" the same gene in multiple species.
12. Koopman and colleagues' explanation for the mouse's sterility is that "the presence of two X chromosomes in a male mouse always results in sterility. . . . It was therefore not surprising that the sex-reversed transgenic mouse m33.13 was also sterile" (1991, 119).
13. Interview with Giovanna Camerino, professor of human genetics, University of Pavia, Italy, October 10, 2000.
14. Leydig cells produce the hormone testosterone when stimulated by another hormone. The anti-Müllerian hormone is a protein that inhibits the development of the ducts in a male embryo. If not inhibited, these ducts develop into the upper vagina, cervix, uterus, and oviducts. The ducts disappear as the male develops.
15. This complexity applies to even a limited definition of epigenetics. See the special issue of *Science* on epigenetics (Riddihough and Pennisi 2001), especially the exchange about the devolution of the term (Wu and Morris 2001).
16. However, Cynthia Kraus finds that Drosophila sex determination research "does *not* provide a good example of androcentrism—but, rather, provides a counter-example" (2000, 152). She uses this case to argue for a reconsideration of feminist critiques of science.
17. See also Dabovic et al. 1995; Graves, Camerino, and McLaren 1995; Zanaria et al. 1995; Swain et al. 1996
18. See also Parker, Schimmer, and Schedl 1999.
19. Prokaryotes are organisms like bacteria whose DNA is not enclosed in a nucleus. Eukaryotes are usually multicellular organisms whose DNA is encased in a nucleus.
20. Interview with Camerino.
21. Ibid.
22. Ibid.
23. On third sexes, see, e.g., Serena Nanda (1989), who writes on the Hijras in India, and Gilbert Herdt (1996), who writes on Two-Spirit people (formerly called berdaches) in the United States.
24. See also Stone 1991; Bornstein 1994; Bolin 1996; Feinberg 1998; Stryker 1998. For a history of transsexuality, see Meyerowitz (2002).
25. An exception is Melanie Blackless et al. (2000), who argue against binarism even at the level of chromosome composition, not just gonads and reproductive organs. Phoebe Dewing et al. (2003) find differential gene expression between the developing brains of male and female mouse embryos and hypothesize that gonadal hormones may not be the only influence on male-female sex differences in brain development and behavior. This research should be carefully examined.
26. See Hacking (1992) and Fujimura and Chou (1994) on self-authenticating practices in laboratory sciences.
27. This point further distinguishes the research of Camerino and her collaborators on determinations of female sex.
28. This use of *frames of reference* is taken from sociologist Erving Goffman's (1986) argument that humans develop and use frames of interpretation to organize and make sense of the events, activities, and phenomena to which they attend in everyday life. Goffman's frames allow us to think of scientists as acting through their formal and tacit scientific training and also through their sociocultural contexts and experiences.
29. Interview with Camerino.
30. Ibid.
31. Ibid.
32. On February 18, 2004, over sixty leading scientists—Nobel laureates, leading medical experts, former federal agency directors, and university chairs and presidents—signed a statement voicing their concern over the misuse of science by the Bush administration. The Union of Concerned Scientists has a Web site that solicits signatures of additional U.S. scientists in support of this effort. See http://www.ucsusa.org/scientific_integrity/interference/scientists-signon-statement.html.
33. On epistemological approaches, see, e.g., Haraway (1988), Barad (1998), Harding (1998), and Longino (2001). On practical approaches, see, e.g., Rosser (2000)

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CHAPTER 31

Imaginary Prohibitions: Some Preliminary Remarks on the Founding Gestures of the 'New Materialism'

Sara Ahmed

We have no interest whatever in minimizing the continuing history of racist, sexist, homophobic, or otherwise abusive biologisms, or the urgency of their exposure, that has made the gravamen of so many contemporary projects of critique. At the same time, we fear—with installation of an *automatic* antibiologism as the unshifting tenet of 'theory'—the loss of conceptual access to an entire thought-realm. (Sedgwick and Frank, 1995: 15)

I was left wondering what danger had been averted by the exclusion of biology. What does the nominative 'biological or anatomical body' actually refer to? And what secures the separation of its inadmissible matter from the proper purview of Irigaray's textual interventions? When I asked a question to this effect it was met with a certain nervous comprehension. Deciding, perhaps, that I must still be immersed in a precritical understanding of the body, the speaker dismissed me with a revealing theatrical gesture. As if to emphasize the sheer absurdity of my question she pinched herself and commented 'Well I don't mean *this* body'. And so it seemed with a gesture so matter of fact that it required no further comment, the fact of (the) matter was both decided and dispatched. (Kirby, 1997: 70)

Feminism has been as deeply implicated in routinized antiessentialism as any of our critical procedures. Even though questions of 'the body' have become increasingly fashionable in all manner of feminist projects (surely 'the body' has become, in a very short space of time, one of our most routinized theoretical gestures), the schedule of feminism's antibiologism has been little altered. In most of these projects on 'the body', the body in question is pursued in its socially, experientially, or psychically constituted forms, but rarely in its physiologically, biochemically, or microbiologically constituted form, the idea of biological construction having been rendered either unintelligible or naive. Despite an avowed interest in the body, there is a persistent distaste for biological detail. (Wilson, 1998: 14–15)

These feminist theories have usually been reluctant to engage with biological data: they retain, and encourage, the fierce antibiologism that marked the emergence of second wave feminism. (Wilson, 2004: 13)

That feminist scholars are particularly prone to a 'knee jerk constructivism' helps explain the reluctance of those in the humanities to engage seriously with the claims of science. (Squier, 2004: 46)

This book functions primarily as a reminder to social, political, and cultural theorists, particularly those interested in feminism, antiracism and questions of the politics of globalisation, that they have forgotten a crucial dimension of research, if not necessary

> to, then certainly useful for more incisively formulating the concepts on which they so heavily, if implicitly rely. It is written as a remembrance of what we have forgotten—not just the body, but that which makes it possible and which limits its actions: the precarious, accidental, contingent, expedient, striving, dynamic status of life in a messy, complicated, resistant, brute world of materiality, a world regulated by the exigencies, the forces, of space and time. We have forgotten the nature, the ontology, of the body, the conditions under which bodies are encultured, psychologized, given identity, historical location, and agency. We have forgotten where we come from. (Grosz, 2004a: 2)

In this position paper, I want to consider what it means for it to be routine to point to feminism as being routinely anti-biological, or habitually 'social constructionist'. I examine how this gesture has itself been taken for granted, and how in turn that gesture both offers a false and reductive history of feminist engagement with biology, science and materialism, and shapes the contours of a field that has been called 'the new materialism' (see Hird, 2004). By constructing feminism as 'prohibiting' an attention to the biological and other matters, this new work is often represented as a gift to feminism in its very refusal to be prohibited by feminism's prohibitions. I will consider what it means for such a gesture to become foundational of a field.[1]

It is important for me to state from the outset that the excerpts I begin with are from feminist scholars whose work I admire, and to whom I myself am indebted. I do not want to reduce this work to the gesture I am identifying. They offer us so much more than a gesture, and when I put that gesture to one side, I find much that is useful and exciting about these books. In posing these questions, my aim is not to dismiss specific feminist work, but to account for how that work might be gathering around a gesture, which if routinized, would have problematic consequences for our understanding of the genealogy of feminist thought. To sustain that gesture as a way of constituting a new field would be, in my view, a way of losing sight.

In offering this position paper, my aim is to open up a debate. In making a case, I risk overstating that case. I am aware for instance that beginning with a list of quotes that evoke this gesture, could be taken to imply that they are all making the same gesture. I think there are important differences. My point is strategic: the gesturing towards feminism's antibiologism has become a background, something taken for granted as a common reference point such that it is not noticeable, and hence has not really been engaged with as involving a specific set of claims.

My viewpoint is partly a matter of an impression that has accumulated over time. I have had numerous conversations with friends, colleagues, participants at conferences, which have involved the use of quite casual forms of expression, which evoke a position that is not held by the speaker. One example of this is the expression, 'I don't think everything is just social', which has been repeated to me a number of times. The sentence works powerfully. It evokes a position that is not explicitly attributed to somebody as a way of making a counterclaim. In other words, it does not say, 'X thinks everything is just social and I disagree with X'. Rather, in evoking a position that the speaker does not hold, you evoke 'somebody' who does think everything is 'just social'. Who, one wonders, would ever make such a claim? Even if the word 'social' was not presumed to guarantee its object, to make that word a descriptor for 'everything' is not only counterintuitive, but also unproductive (as any word would be if used to describe 'everything').

I would suggest that the word 'social' here works metonymically: it acquires significance in part through its nearness to other words such as language, discourse, culture. The speech act might express that familiar or even habitual anxiety that feminism and poststructuralism have reduced 'everything' to language and culture, in what is often referred to as 'textualism', and have forgotten the 'real' of the real world, or the materiality of what is given. As a reviewer of papers for journals, I have lost count of the number of papers that have referred casually, usually without using examples, to how feminism or poststructuralism have not dealt with the body as a real, living, physical, biological entity or have reduced 'everything' to language, signification and culture. That these sentences are repeated without illustration or contextualization is symptomatic of what I call the 'routinization' of the gesture of pointing towards the anti-biologism or constructionism of others, whereby this anti-biologism itself functions as a form of bad faith (we need to be pinched, reminded of the real, returned to the facts of the matter). Rather than feminist anti-biologism or constructionism being routine, I want to focus on the routinization of the gesture towards feminist anti-biologism or constructionism. This is not to say that such a gesture is the only routine for new materialism; to make such an argument would be to repeat the very gesture I am critiquing. But one of the effects of this routinization of the critique of antibiologism is that the critique of this critique risks being read as symptomatic of anti-biologism.

FEMINISM IS ANTI-BIOLOGY

Let's return to these gestures in their specificity. Some of them are specifically addressed to feminism (Kirby, Wilson, Squier), while others are addressed more loosely to 'theory' (Sedgwick and Frank) or 'social, political, and cultural theorists' (Grosz). We have a moving referent, or we could say that the object of critique is itself unstable. It is noticeable in the case of the first book quoted, by Sedgwick and Frank, that they do name a specific theorist and book: Ann Cvetovich's *Mixed Feelings: Feminism, Mass Culture and Victorian Sensationalism.* This book becomes symptomatic of a general trend in 'theory' to be, as they describe it, 'automatic antibiologism'. Now, clearly they are worried by their own gesture. In a footnote they defend their use of a 'sole book as our example in articulating this argument', which they describe as persistence in 'gracelessness' (Sedgwick and Frank, 1995: 27). I am not concerned by their defence of the use of this book as opposed to any other book. But what is striking here is how this book stands alone: even when they comment on their use of this book, they still do not refer to other examples of 'automatic antibiologism'. In reading one book as a symptom of a trend, what are we doing? Does this allow the trend to be posited as internally coherent, framed by the edge of the book, as if it is a book? After all, the argument involves using 'theory' in quotation marks. Who is or does theory, one wonders? What about the work of science studies scholars who have worked on and with the biological, in different ways? Do they belong in 'theory'? I want to suggest 'theory' is being constituted as anti-biological by removing from the category of 'theory' work that engages with the biological, including work within science and technology studies, which has a long genealogy, especially within feminism. Such work disappears in the very argument that we must return to the biological.

For Elizabeth Grosz the argument is framed as a matter of return. We must 'return' to concepts of nature, matter, life (Grosz, 2004a: 2). That we need to return to these concepts, she suggests, is a sign of forgetting, 'we have forgotten where we have come from' (Grosz, 2004a: 2). One must wonder who is being evoked by this 'we', and to what extent this 'we' functions to interpellate the reader into a community that shares a common horizon (Have you forgotten where we have come from? Have I?). If you inhabit the 'we' of feminism, then you become implicated in this 'we' by virtue of your inhabitance. After all, this text is very much addressed to feminists and others who share feminist interests, suggesting that feminists, and 'all theorists interested in the relations between subjectivity, politics, and culture, need to have a more nuanced, intricate account of the body's immersion and participation in the world, if they are to develop political strategies to transform the existing social regulation of bodies' (Grosz, 2004a: 2). In other words, the point of 'returning' to biology, evolution and vitalism (represented by Darwin, Bergson and Nietzsche—the book is primarily a close reading of these three writers) is to produce feminist knowledge that can enable political transformation. And yet if this book is as it were for feminism, then why does it not engage with feminism? Grosz does mention two feminist responses to Darwin, citing the work of Sue Rosser and Fiona Erskine. Grosz reads them both as examples of 'the standard, knee-jerk feminist reading' (Grosz, 2004a: 71) and although they are quoted, neither of the quotes is engaged with. They stand only as symptoms. She then suggests that rather than 'providing criticisms of Darwin's sexism' (Grosz, 2004a: 73), she wants 'to see what of Darwin, and the philosophical figures that follow him, may be of use to a feminist politics of transformation' (Grosz, 2004a: 73).

What is striking here is how the history of feminist responses to Darwin is reduced to 'standard, knee-jerk' readings of pointing out sexism (read: automatic bodily reaction). The idea that such feminist responses are knee-jerk and automatic implies they are unthinking, perhaps even bodily responses that prove the truth of biology at the moment of its denial. I would argue that there is nothing automatic about feminist critiques of sexism. Indeed, this under-describes the philosophical and political contribution of 'pointing out sexism' (if sexism is structural rather than incidental to philosophy, as generations of feminist philosophers have shown us, including Grosz, then pointing out sexism remains a revolutionary and affirmative task, and a major contribution to any feminist project of transformation). It also does not appreciate the range of feminist responses to Darwin over time, not all of which were oppositional or worked by pointing out sexism within evolutionary thinking (for a summary of this range, see Gowaty, 1997).

Not only is the history of feminist scholarship on biology and science missing from *In the Nick of Time,* other than the two aforementioned examples of feminist critiques of Darwin, but Grosz does not engage with any of the more recent work within feminist science studies, which has engaged with the question of biology, materiality, life itself: such as represented by the work of Donna Haraway, Evelyn Fox Keller, Emily Martin, Sandra Harding and Sarah Franklin.[2] It is not enough to say that this is simply an omission (although as an omission it is striking), and incidental to the arguments of the book. Instead, the argument relies on the omission. You can only argue for a return to biology by forgetting the feminist work on the biological, including the work of feminists trained in the biological sciences. In other words, you can only claim that feminism has forgotten the biological if you forget this feminist work.

You could argue, as does Elizabeth Wilson, that feminism's anti-biologism proceeds not so much as a forgetting, but takes the form of opposition to, and rejection of, the biological as a sphere of life, as well as a form of knowledge. She represents second-wave feminism as 'fiercely antibiologist' (Wilson, 2004: 13). I want to comment, first, on the use of the adjective 'fierce'. The adjective is used of course not to describe feminists but to describe the anti-biologism that Wilson attributes to second-wave feminism. At the same time, this word evokes a caricature of the second-wave feminists: the fierce feminist tendency to be 'anti' is often evoked as some kind of pathological figure; she is angry, a kill-joy, perhaps even a freak. Elizabeth Wilson also describes such feminists as having a 'distaste' for biology. This description is deeply psychologizing, almost suggesting that the problem here is interior to feminism, as a kind of biophobia. The 'knee-jerk constructionism' that Squier describes translates this phobia into a tendency: the biophobia is what then would 'explain' the turn to constructionist models. Such a caricature of the second-wave feminist prevents us from engaging more closely (and perhaps generously) with the work of second-wave feminists.

Of course, many second-wave feminists did offer powerful critiques of the use of biology as a way of defending social roles ('biological determinism'). Their critiques were very important: there is no doubt that biology can be used to present social relations as products of nature not only within science, but also within government and public culture given the associations the word 'biology' has with what is given or already decided. But we do not need to read this critique as a rejection of the biological as such, but rather as a critique of the presumption that biology is fixed or decided. In other words, the feminist critiques of the uses of biology to defend gender hierarchy need not be read as symptomatic of anti-biologism, even if they are against a specific model of biology (just as the, critique within critical race studies of the uses of 'culture' to defend racial hierarchy does not mean being anti-culture, although it is anti a particular model of culture). After all, these points of critique of biology were always points of divergence between feminists, meaning that what constitutes 'biology' has been a question rather than solution for feminist thought.

In other words, feminists have produced very different kinds of critique of the role of biology, not all of which depend upon the rejection of the biological as a sphere of life. To describe the second-wave feminists as 'anti-biology' is a reduction of the complexity and heterogeneity of feminist work in this period. To say that feminism today has inherited this anti-biologism extends the violence of this reduction. Indeed, what is striking when you return to some of the feminist work on biology written in the 1970s and 1980s is the care taken in how the biological is evoked as a category. In particular, many feminist writers very carefully differentiate their object of critique from 'biology as such', whatever 'biology as such' might or could mean. For instance, we could read the following sentence from Deidre Janson-Smith's (1980: 65) article, 'What is Socio-Biology', as symptomatic of anti-biologism: 'The Women's Liberation Movement has with good reason reacted strongly to the use of "biological" arguments in the definition of the female; these have all too often been merely a confirmation of the patriarchal *status quo*.' Janson-Smith does not address her critique to 'biology as such', but rather to the use of biological arguments to confirm the patriarchal status quo. She attends specifically to the use of genetic arguments. As she describes, 'Inasmuch as we are made up of cells, controlled by genes, all that we do has a genetic basis. There are no learning processes that do not have *some* genetic limits, but there are few, if any, behaviors that are dictated entirely by the genes' (Janson-Smith, 1980: 65). Janson-Smith's work shows how the problem occurs when genetics is taken up as if it dictates behaviour, which is not to say that genetics does not shape in some way what we do. Speaking more generally, the problem occurs when biology becomes used as an explanation of behaviour, which is not to say that biology does not shape in some way what we do.

Feminist work on biology written during this period offers us a very rich archive of how we can think 'this some way'. Lynda Birke's *Women, Feminism and Biology* (1986) begins with the following statement: 'this book is founded upon my belief in the relevance of biology to feminist thought: that relevance is not, however, biologically determinist, as I hope the following pages will indicate' (Birke, 1986: x). Here the critique is directed towards biological determinism and not to biology as a sphere of life: indeed, the background to the critique is clearly an assumption of the relevance of biology. Likewise, Janet Sayers in *Biological Politics* (1982) discusses the 'number of ways in which opponents of feminism have sought to appropriate biology for their cause'. As she goes on to argue, 'although feminists have been accused of neglecting and ignoring biology, they have in fact suggested a number of ways of accommodating the facts of biology in their analysis of women's situation' (Sayers, 1982: 107). *Biological Politics* argues explicitly that the problem is with how biology has been appropriated to support sexism, which necessarily involves an assumption that biology is not itself inherently sexist.[3] What is also clear is that the myth of feminism as anti-biology is itself part of the appropriation of biology. Sayers (1982: 173) notes how 'writers have berated feminists for not taking account of biology'. The figure of the anti-biological feminist has a long genealogy, which is inseparable from anti-feminist uses of biology.

The point of the feminist critique of the appropriation of biology was to accommodate biology into an alternative analysis of women's situation. Such a concern with accommodating rather than excluding biology as a sphere of life meant that much second-wave feminist thought offered rich analyses of human beings alongside other forms of biological life. For instance, Deidre Janson-Smith, who I quoted earlier, suggests that: 'I see no reason to regard humans as other than biological beings, or to erect great barriers between humanity and the more "primitive" forms of life' (Janson-Smith, 1980: 66). Indeed, although Elizabeth Wilson (2004: 1) chastises second-wave feminism for being 'reluctant to engage with biological data', much of this literature involved very close detailed analysis of biological dimensions, often generated through a political as well as epistemic commitment to describing the biological processes of women's bodies, such as menstruation. Just note the detail in the following description, again taken from Janson-Smith's article:

> There are many changes in the body's functions, as well as in the behavior that occur during the cycle. Brain waves (as measured by the electroencephalogram) are affected by the cycle, so that epileptic fits are least likely between ovulation and premenstruum, and most likely just before a period. Various other functions change, such as carbohydrate metabolism (the rate at which sugars are used by the body), thyroid function, mineral and water balance, resting temperature, and sensitivity to smells. (Janson-Smith, 1980: 98)[4]

This commitment to rich description of biological processes was generated by women's activism: the women's health movement, for instance, involved new understandings of women's bodies, which required engaging with the biological sciences often critically, but also very closely. We only have to read *Our Bodies, Ourselves* (first published 1973) to see evidence of how this engagement with biological data provided a productive point of entry for feminist politics.

As soon as we turn to feminist work on biology, the argument that feminism was anti-biology looks at best a caricature. If anything, we could argue that recent feminist work on embodiment is very indebted to this earlier feminist engagement with biology. To acknowledge such debts is not to prohibit critique. Internal critique is an important part of a feminist inheritance. But to caricature past feminisms is not to engage in critique: the work of critique is a form of intellectual work that requires engaging closely with a range of work (almost all the books I cite here use one or two examples of feminist or theoretical anti-biologism to illustrate their arguments). Many of the books referred to here under the rubric 'the new materialism' do involve generous forms of critique, but in relation to a scholarship they imply is insufficiently engaged with by feminists/theorists: Tomkins is read very carefully by Sedgwick and Frank, while Darwin, Bergson and Nietzsche are read lovingly by Grosz. What is evident here is an uneven distribution of the work of critique, which is after all a labour of love. To be blunt, male writers (who are also usually dead and white) are engaged with closely, while feminist writers are not. What does this uneven distribution of attention and care actually do?

It is possible to recuperate anything for feminism (well almost). We must and can make pragmatic choices about what to read, what to do with what we read, what we cite and how we cite it. I am not saying we should only read feminist work as feminists; that we should return only to this archive. And yet, there is a politics to how we distribute our attention. All I want to suggest is that if we read the work of feminists writing on biology with the same amount of time and care, it might be harder to describe such work as anti-biologist. What is clear then is that the gesture of pointing to feminist anti-biologism either excludes feminist work on the biological from what counts as theory; forgets feminist work on the biological by arguing that we have forgotten the biological; or recalls that work by reading it as a symptom of anti-biologism.

When returning to these critiques of feminist anti-biologism, I was reminded very much of the evocation of political correctness as a form of prohibition against certain kinds of speech. In this argument, it is because of a habitual political correctness (the liberal intelligentsia) that we are not allowed to say this or that (e.g. a racist joke). The implication goes: by saying 'this' or 'that' we are fighting against the prohibition. The words become a symbol of refusing a prohibition and the justice of free speech. Perversely, this is how a racist joke can be spoken in the name of freedom. Not only can we detect here a structuring desire for certain words to be prohibited, but also an inflation of the very power of the 'whoever ' that is doing the prohibiting: as if the world that says 'this or that is bad' is the dominant, hegemonic world, which demands consent. In this world, racism becomes the minority position, the racist, or the sexist, is the one who is not allowed to speak. I call this an 'inflationary logic'.

I would argue that the speech act that proceeds by refusing the prohibition against speaking about biology involves this inflationary logic. No doubt this is a potentially awful analogy. Let me say here it is not the content of the speech act that is imagined as prohibited that concerns me. Rather it is the form of the speech act itself. In both these cases (biological arguments against anti-biologism, anti-pc arguments against pc), the speech act works by constructing an 'imaginary prohibition', which is then taken as foundational to a given speaking or intellectual community. That prohibition is imagined as hegemonic, as a majority position, in order to constitute the speech act, as a minority position, even as a kind of defence against free thinking, a rebellion against orthodoxy.

The speech act that calls for us to 'return to biology' constructs the figure of the anti-biological feminist *who won't allow us to engage with biology,* and inflates her power.

Let me give another example. Someone says during a seminar 'you have to be a social constructionist to get research funding from the ESRC [Economic and Social Research Council]'. The speaker makes reference to postmodern and feminist theory as part of his general critique of social constructionism. Actually, if we examine recent developments in the ESRC around requirements for social science postgraduate training, we might be tempted to say that the ESRC relies on a rather more conservative definition of what counts as knowledge within the social sciences. As a funding body, it polices what counts as social sciences, and excludes for instance any projects within women's studies or cultural studies that employ anything other than what are seen as properly 'social science' methods. I have to confess I rather wish that the ESRC would be infiltrated by social constructionists, although I am not quite sure what they look like! For such a body to be identified as aligned with 'social constructionism', whatever that means, is not only fantastic, but also involves the inflation of the power of this theoretical framework, such that it becomes seen as defining the very material conditions of academic value. We are not far off here from the right-wing reading of academia as having been taken over by liberals and radicals who have turned away from the proper objects of academic knowledge. Again, one wishes!

Immediately, then, kinds of work defined as not social constructionist, not feminist, not postmodern (the slide between these positions participates in the logic of inflation) are constructed as the minority position, the injured other, as the 'who' that must be freed. The very gesture towards biology imagines itself as a prohibited speech act. Just as with the inflationary rhetoric of political correctness, we now have the defence of a return to biology (which is after all a highly funded discipline and a much valorized term within the general economy) as a form of free speech.

CREATING A 'NEW MATERIALISM'

Such gestures become foundational as they allow the implication that the theorist is embarking on a heroic and lonely struggle against the collective prohibitions of past feminisms. In other words, the gesture does something not only through how it constitutes feminism as an object (either in its presence or absence) but also through how it constructs the intellectual project of this new work. This work is often described as 'the new materialism' (see Hird, 2004). The new materialism does not take as its point of entry a critique or engagement with historical materialism, which does not haunt this emergent field even in its absence. Rather the point of entry for the construction of this field is the critique of past feminism for not engaging with matter, as such. The critique of feminist antibiologism becomes, in other words, a more general critique of a feminist refusal to engage with 'matter as dynamic and alive', as Patricia Clough (2007: 8) describes. Feminism it seems has forgotten how matter matters.

This narrative of a forgetful feminism involves an emphasis on feminism as being 'limited' by its own preoccupation with culture. Myra Hird's account of the emergence of 'the materialism' has the following section heading: 'The Limits of Feminist Theories of Culture'. Within this section, she cites Elizabeth Wilson's critique of 'feminist analyses of materiality that remain determinedly fixed in the cultural domain' (Wilson, 2004: 22). We can see even in these two citations that the object of critique is unstable: in the first claim, feminist theories of culture are limited (as they don't engage with materiality), and in the second, feminist theories of materiality are limited (because they reduce materiality to culture). So either feminism is limited given its emphasis on culture, or given its reduction of whatever it engages with to culture.

In most of these feminist critiques of feminism, Judith Butler is singled out as a primary example of a feminist who reduces matter to culture (see Barad, 2003; Clough, 2007: 8; Cheah, 1996; Fraser, 2002). It is important to note here that Butler does attend to the question of matter: she offers a definition of matter as 'the effect of boundary, fixity and surface' in *Bodies That Matter* (Butler, 1993: 9). For Butler, matter is an effect of a process of materialization. We should note, however, that her definition is offered within a specific context; at this point in the book, she is engaging with Foucault in order to reconsider how bodies materialize; and how sex involves a dynamic process of materialization. Within this context, her argument about materialization supports an argument about the sedimentation of bodily norms over time. She is not offering in this book a theory of the material world, but a theory of how sex materializes or becomes worldly. In my view, her definition of matter as an effect of a process of materialization, which is a theory of matter as temporal, could be used or extended to other forms of materialization. Butler does not do this, for sure; it is not her project in this book. And yet, her argument does not exclude this possibility even if she does not herself explore it. Butler is read as if she were offering a theory of the material world in the very critique of how she reduces that world to 'discourse' or 'culture'. In fact, if anything, *Bodies That Matter* offers a powerful exploration of how histories are sedimented in the very 'how' of bodily materialization: it makes sex material, even if it does not offer a theory of the coming into being of the material world, as such. To ask it to do so would seem unjust: as if accounting for the materiality of sex is too partial, not enough, insufficient. The reading of Butler as anti-matter seems to be motivated, as if the moment of 'rejection' is needed to authorize a new terrain.

The argument that feminism has reduced matter to culture, I would suggest, loses its object somewhere along the way. This is not to deny how much culture might matter for feminism. Given the feminist concern with understanding how gender and sexuality are reproduced in time and space, a key emphasis has been placed on language, culture, the symbolic, labour, discourse and ideology. This is because feminism needs a theory of social reproduction; of how particular forms become norms over time. But it does not follow that feminists don't then believe that the material world exists, or that feminist theory cannot admit to the materiality of things. If anything, given the concern with the social reproduction of hierarchies, much feminist work might point to the complexity of the relationship between materiality and culture, rather than reducing one to the other.

Feminist work in science studies, for example, which must be read as intrinsic to feminist theory rather than apart from it, explores the traffic between nature/biology and culture, as a 'material-semiotic' to use Donna Haraway's (2003: 201) classic term. The new materialism almost seems to return to old binaries—between nature/materiality/biology and culture in the very argument that 'matter' is what is missing from feminist work. This is evident in Karen Barad's work, an important commentator within this emergent field. Her paper 'Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter' (Barad, 2003) begins with the following argument:

> Language has been granted too much power. The linguistic turn, the semiotic turn, the interpretative turn, the cultural turn: it seems that at every turn lately every 'thing'—even

> materiality—is turned into a matter of language or some other form of cultural representation. The ubiquitous puns on 'matter' do not, alas, mark a rethinking of the key concepts (materiality and resignification) and the relationship between them. Rather, it seems to be symptomatic of the extent to which matters of 'fact' (so to speak) have been replaced with matters of signification (no scare quotes here). Language matters. Discourse matters. There is an important sense in which the only thing that does not seem to matter anymore is matter. (Barad, 2003: 801)

Barad is offering a caricature of 'the turns' in recent theory, although no examples are provided to illustrate the argument. We have no idea of who she is actually referring to (other than those who use 'matter ' as a pun). Matter here is what matters, as a position that defends itself against theories that make what really matters (matter) disappear. She implies here that theorists are suspicious of the facts of the matter—but not of culture: as if now we trust in words, not things. We are thus scared by—we put scare quotes around—the word 'fact' but not the word 'signification'. So Barad (2003: 801) asks, 'How did language come to be more trustworthy than matter?' One could note here that the poststructuralist critique of language was that words are far from trustworthy, and that they do not give us direct access to things: I would even say that the poststructuralist turn begins with a suspicion with words as much as things.

This caricature of poststructuralism as matter-phobic involves a rather mournful lament: a call for a return to the facts of the matter that new materialism (rather ironically perhaps) shares with critical realism. We are witnessing perhaps an attachment to this lament. In Barad's paper, the caricature of whatever is the object of critique here (I say whatever because Barad, unlike other critics mentioned, does not name feminism, but simply evokes these 'turns' perhaps as general 'turns' within intellectual thought, using what I have described earlier as an inflationary logic) disappears as an explicit aspect of the argument. Instead, Barad creates her caricature by saying what she is not saying. So she argues against something or somebody throughout: 'Discourse does not refer to linguistic or signifying systems' (Barad, 2003: 819); 'Discursive practices are not speech acts, linguistic representations, or even linguistic performances'; 'discursive practices are not anthropomorphic place-holders for the projected agency of individual subjects, culture or language'; 'matter, like meaning, is not an individually articulated or static entity'; 'Matter is not little bits of nature'; 'matter is not a support, location, referent or source of sustainability for discourse'; 'Matter is not immutable or passive' (Barad, 2003: 821), and so on. Her writing evokes the existence of an argument that discourse 'is' this, or matter 'is' this by arguing that it is 'not' that, where the 'that' is an argument that is not attributed to somebody. The new materialism takes shape by the mobility and detachability of this 'not'.

I would argue that the very claim that matter is missing can actually work to reify matter as if it could be an object that is absent or present. By turning matter into an object or theoretical category, in this way, the new materialism reintroduces the binarism between materiality and culture that much work in science studies has helped to challenge. Matter becomes a fetish object: as if it can be an 'it' that we can be for or against. What we might be encountering here is a desire for a pure theoretical object: whether that object is described as biology, matter, or affect.[5] But such objects are invented, and when they are held in place then we are less able to do justice to the complexity of how all sorts of different things cohere. To include biology or materiality in the work that we do would be to give up the idea that they exist as objects that are given and which our task is simply to uphold.

Indeed, as I have suggested, earlier feminist work on biology and matter emphasizes precisely the entanglements and traffic between nature/biology/culture and between materiality and signification (see Franklin, 2003; Haraway, 2003). Indeed, returning to Haraway's monumental book *Primate Visions*, published in 1989, we can see the force of this commitment to thinking of the traffic between nature and culture. She describes the book in the following terms:

> *Primate Visions* does not work by prohibiting origin stories, or biological explanations of what some would insist must be exclusively cultural matters, or any of the enabling devices among primate discourses' apparatuses of bodily production. I am not interested in policing the boundaries between nature and culture—quite the opposite, I am edified by the traffic. (Haraway, 1989: 377)

Haraway's work shows us how following the traffic means letting go of proper objects, including disciplinary objects: biology, culture, the social and so on. Things usually happen when the objects of our theoretical work fall apart, when things get messy. What counts as biology and materiality within the sciences is after all a subject of debate and dispute. New developments in thinking within all disciplines—the sciences, social sciences and humanities—often proceed from the collapse of their objects.

In claiming to return to matter, we might then be losing sight of how matter matters in different ways, for different feminisms, over time. The gesture is a forgetting as well as a caricature. Of course, I have no doubt reduced the complexity of the work I am engaging with. I was compelled to write this piece—by frustration, I admit. If my argument against such gestures means anything it means this: when we describe what it is that we do, when we consider how it is that we arrive at the grounds we inhabit, we need to appreciate the feminist work that comes before us, in all its complexity. We don't always have to make a return to earlier feminist work, but if we represent that work as being this or that, then we need to make that return. Such a return would be ethical: we should avoid establishing a new terrain by clearing the ground of what has come before us. And we might not be quite so willing to deposit our hope in the category of 'the new'.

NOTES

I would like to acknowledge my debt to Sarah Franklin: our many conversations on the feminist critique of feminist anti-biologism have shaped the arguments I develop here.

1. This gesture is not specific to feminists working in the area of new materialism. I have recently heard examples of this gesture in critical race studies, where scholars have argued that we need to return to the 'matter ' of race, and get beyond the focus on race as construction or image, with its compulsive focus on racism as arbitrary. They often do so by representing other work in the field as prohibiting talk about biology and matter. One speaker at a conference even argued that Audre Lorde and Fanon reduced racialized bodies to 'body image') (which clearly neither of them do) and that Deleuze and Guattari offered a better alternative to thinking how the body comes to be racialized (as assemblages). For an example of this argument for rethinking the materiality of race that critiques other work for conceiving race 'as a problem of language' see Arun Saldanha (2006).
2. In *Time Travels: Feminism, Nature, Power*, Elizabeth Grosz (2004b) does engage more directly with feminist approaches to biology and Darwin, referring both to Janet Sayers' (1982) *Biological Politics*, and Patricia Gowaty's (1995) edited collection. She acknowledges that 'Some feminist theorists have made tentative approaches to a theoretical analysis of Darwin's scientific contributions' (Grosz, 2004b: 14). However, in both cases, she moves quickly to a critical language: Sayers 'sadly . . . leaves [Darwin's] social and political implications largely unanalysed' (Grosz, 2004b: 15) and Gowaty 'reduces both Darwinism and feminism to positions on two sides of a mutual divide' (Grosz, 2004b: 15–16). What follows then is an entirely uncritical and redemptive reading of Darwin, based on the idea that Darwin can give feminism something it lacks: 'we need to look again at his texts with the desire to see what

they may be of value for providing feminist theory with richer and more subtle intellectual resources to both attain its aims and refine its goals' (Grosz, 2004b: 18), which in turn positions feminism rather passively as a recipient, as receiving wisdom. It is also worth noting that in this book, Grosz suggests that 'it is only recently that feminist theorists in the humanities and social sciences have exhibited an openness toward biological research' (Grosz, 2004b: 217), which ignores the longer genealogy of feminist science studies: one thinks of classics such as *Alice Through the Microscope,* produced by the Brighton Women and Science Group in 1980 (Birke et al., 1980), which involves contributions from feminists based in humanities and social science disciplines; or books like *The Woman in the Body,* published by Emily Martin (1987), which contributed to the analysis of science as culture. Indeed, we could turn to the edited collection *Off-Centre: Feminism and Cultural* Studies (Franklin et al., 1991), which contains a section titled 'Science and Technology' (with individual contributions from Maureen McNeil, Sarah Franklin, Wendy Fyfe, Deborah Lynn Steinberg and Tessa Randles) and reminds us that feminist cultural studies and feminist science studies have a shared genealogy. We also need to recognize that many of the feminist theorists trained in the biological sciences actually work in, and contribute to, humanities and social science disciplines (e.g. Donna Haraway, Sandra Harding, Evelyn Fox Keller, Lynda Birke and Ruth Hubbard). The history of feminist science studies is exemplary as a history of the willingness to cross the borders between the humanities, social sciences and biological sciences. This interest in the biological sciences cannot thus be described as recent for feminists in the humanities and social sciences, though of course it might be the case that a more specific group of feminist theorists have become interested in biology and science more recently.

3. Reading *Biological Politics,* it was striking that 'biology' is not the only object of critique. For example, the use of biological arguments to support sexism is contrasted to the use of 'social constructionist arguments against women' (Sayers, 1982: 120). Indeed, if we think of the feminist critique of biology as part of the broader feminist critique of epistemology, then we can see how much feminism presses against the boundaries of all forms of disciplinary knowledge: including linguistics, psychology, history, sociology, economics and literature. Such pressing points are also points of engagement.
4. Or take Anne M. Briscoe's wonderful article published in 1978 on 'Hormones and Gender ' which gives a detailed account of endocrinology, 'the study of the glands or tissues that manufacture chemical compounds (hormones) with special physiological activity and which release or secrete these agents into the circulating blood to influence cells at a distance from the cells of origin' (Briscoe, 1978: 32). Her account of hormones and gender attends to these physiological processes:

> Those hormones that are concerned with sexual phenomena are also qualitatively the same in both sexes. They are produced and released by the following scheme: the pineal gland, which regulates the hypothalamus; the hypothalamus secretes hormones that regulate the rate of pituitary hormone secretion; the anterior lobe of the pituitary gland secretes hormones that control the gonads and mammary glands; the gonads in turn secrete sex hormones in response to stimulation by pituitary hormones called gonadotropins; the adrenal cortex or cortices secrete sex hormones in response to stimulation by another of the pituitary hormones, ACTH or the adrenocorticotropic hormones. (Briscoe, 1978: 33)

5. I would also argue that recent work on 'the autonomy of affect', which relies on the sharp distinction between affect and emotion, repeats some of the gestures that are foundational within the new materialism (see Massumi, 2002). Elspeth Probyn (2005: 11), for example, describes affect as biology and emotion as culture, which creates a 'basic distinction' between biology and culture. While this argument is an important critique of the failure to recognize the biological aspects of emotion in cultural studies, or the cultural aspects of emotion within the biological sciences (Probyn, 2005: xv), it might be useful to challenge the distinction itself: to explore how culture and biology are mutually implicated; how neither are given, how they shape and inform each other.

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CHAPTER 32

From Science and Technology to Feminist Technoscience

Jutta Weber

INTRODUCTION

> taking responsibility for the social relations of science and technology means refusing an anti-science metaphysics, a demonology of technology, and so means embracing the skillful task of reconstructing the boundaries of daily life . . . It is not just that science and technology are possible means of great human satisfaction, as well as a matrix of complex dominations . . . It means both building and destroying machines, identities, categories, relationships . . . (Haraway, 1985: 181)

In most of contemporary Western theory, science and technology are regarded as a central part of culture with discourses and practices tightly interwoven with our daily lives. In the mid 1980s, when feminist science studies scholar Donna Haraway wrote the lines cited above, this understanding of science and technology was not self-evident. Science was often thought of in terms of classical sciences, such as physics, mathematics, biology, or chemistry, disciplines many of us 'well-educated girls' were not very fond of at school. In the Cold War period, most science studies scholars directed their attention towards so-called 'Big Science' (Price, 1963). Researchers equated science and technology with hierarchically organized scientific and technological projects planned and undertaken by governments and the military. Huge technological systems like nuclear power plants, weapon systems, and undertakings like the Manhattan Project or ARPANET[1] were the prototypes of the technology of that time. No wonder that feminist or critical theory stressed science and technology as 'masculine culture' (Wajcman, 1991), partly driven by masculinist dreams of omnipotence or ruled by fantasies of death (Keller, 1985). Equating science and technology with government projects and the military often led to a 'demonology' of technology in feminist and other critical theory.

A good example is the critique of reproduction technologies in the 1970s and 1980s. These technologies were regarded as not driven by fantasies of death, but by the longing to unveil the secrets of life. Since the birth in the 1970s of Louise Brown, the first *in vitro* fertilization child, reproduction technologies evoked fears of masculinist appropriation of women's reproductive abilities, leading to a repressive population policy. There were many women activists fighting against these new technologies, like the well-known group FINRRAGE, founded by Gena Corea, Maria Mies, and others. To them, reproductive technologies turn the female body into a laboratory for the industrialized production of living beings (Corea et al., 1985; Wajcman, 1991). These technologies were regarded as another means to prolong the subordination of women. Shulamith Firestone (1970) was one of the few feminists who celebrated the new reproductive technologies as a possible means to liberate women.

TECHNOLOGY, SCIENCE, AND MASCULINITY

Technology is often described as a genuine 'masculine culture' grounded in patriarchal structures, gender relations, and identity politics. While some feminists interpreted the desire for technologies as grounded in a 'natural' tendency of men towards aggression and an obsession with control, others insisted on distinguishing 'between different forms of masculinity in relation to different areas of technology. To say that control over technology is a core element of masculinity is not to imply that there is one masculinity or one technology' (Wajcman, 1991: 143). Not only does this view stereotype masculinity, but other feminists reminded us that the emphasis on male-dominated technologies like the cyber and life sciences 'reproduces the stereotype of women as technologically ignorant and incapable' (Wajcman, 1991: 136). Against this view, Ruth Schartz Cowan and Judith Wajcman, among others, stress the importance of the 'technological revolution in the home' (Cowan, 1976: 33).

The feminist lack of interest in science and technology studies until the late 1980s was mostly grounded in the understanding of science and technology as military-biased 'Big Science' and 'masculine culture', while household technologies, new media, as well as new technosciences were, for the most part, disregarded. The increased use of television, video, cable, personal computers, and other developments in communication and information technology as well as the proliferation of biotechnology in agriculture, medicine, and procreation challenged the identification of science and technology with centralized, top-down research projects and huge technological systems. Since the late 1980s, it has become more and more obvious that science and technology are deeply interwoven into our everyday lives.

Donna Haraway (1985), Elvira Scheich (1989), and others have shown how central humanist concepts like nature, body, and identity get refigured through technoscientific discourses and practices. The relations of nature and technology and concomitantly those of gender are profoundly reshaped in the process of appropriating nature in Western societies, facilitating the idea of the co-construction of science, technology, society, and gender. To give an example, when reprogenetics or sex change becomes a common commercial practice for many people or care robots are developed to take over the former 'feminine' task of caring for children or sick people, old borders between sex and gender, between private and public, between a so-called masculinist technology and a feminine *Lebenswelt,* implode. The constructionist move in feminist and other science studies challenges the borders of the social and the technoscientific.

Feminist theorists also articulated a new bonding of technoscience with transnational capitalism, arguing that new technologies contribute to 'increasing capital concentration and the monopolization of the means of life, reproduction and labor' and to 'global deepening of inequality' (Haraway, 1997: 60). The effects are twofold. On the one hand, relations of domination are becoming more complex and opaque. On the other hand, the reshaping of central categories through technoscientific practices opens up new options for refiguring gender, nature, and sociotechnical systems. As structures of domination are getting more and more complex and the reshaping of old hierarchical categories seems possible, the demonology of technology appears more and more inadequate as a critical attitude towards our technoscientific culture.

CONTINUING THE STORY

Today's feminist critique often uses the former demonology of technology as a point of departure to tell a story of progress from liberal to postmodern feminism.[2] According to this narrative, liberal and Marxist feminist critiques failed to critically analyze science and technology because they considered the latter as neutral or did not pay attention to the symbolic dimension of technoscience. However, the Marxist feminist critique is acknowledged at least for analyzing gender in terms of social structure, while it is conceded that radical and ecofeminist approaches successfully elaborated the symbolic dimensions of science, technology, and masculinity. However, these perspectives are blamed for locating 'women's essence . . . in their biology' (Gill and Grint, 1995: 5). Unlike the liberal and Marxist feminist approaches, early social construction feminism understood that 'women's alienation from technology is a product of the historical and cultural construction of technology as masculine'. Social construction, however, did not succeed in fully explicating 'the relations between the key terms, "men" or "males", "masculinity" and "patriarchy" ' (Gill and Grint, 1995: 12).

I have deliberately exaggerated this somewhat Hegelian story of progress to clarify my argument that as knowledge is situated, it always takes a perspective. The problem is how to write a *non-linear and complex* historiography of theories and practical engagements, as well as the artifacts of science and technology. It might help to avoid linear stories of feminist theory by reflecting not only on the epistemological and ontological framework of earlier approaches, but also by rethinking these frameworks in the light of contemporary sociopolitical developments as well as prevailing technological practices, artifacts, and material cultures.[3]

Recent studies question essentialist understandings of science and technology partially because of their cumulative fusion. When science, technology, society, and industry amalgamate into dense networks, and the sociocultural and the technological are tightly interwoven, the idea that a masculinist technology determines a feminine *Lebenswelt* appears ridiculous. Technology as an intimate part of our lives is no more the 'Other', as it was often understood in the age of 'Big Science', but rather part of our human condition. The demonization of technology becomes counterproductive as it hinders understanding of our life conditions in the age of technoscience and the refiguring of ontological realms of science, technology, society, and gender.

I will, therefore, tell my story of feminist science and technology studies in this chapter using a situated sociocultural and historically grounded approach. I concentrate on the close ties between changing theoretical approaches of science and technology studies and the material, symbolic, and sociopolitical dimensions of science and technology. My aim is to develop a stance which goes beyond euphoric affirmation or pessimistic refusal of technoscience, and, rather, articulates a perspective from which the omnipresence of technoscientific discourses and practices in every realm of our daily lives becomes visible and thereby available for analysis.

GENDERED AND OTHER CRITIQUES OF SCIENCE

In the first decades of women's studies in the 1960s and 1970s, it was mostly women scientists confronted with discrimination via institutional and gender identity politics who engaged in critical science and technology studies.[4] They reconstructed the achievements of other women scientists, rendering them visible for a broader audience and analyzing the mechanisms of their exclusions.[5] By discovering the large number of women scientists who had to live on the margins of intellectual and academic life, they contributed to a growing mistrust of the self-ascribed values of neutrality and objectivity in science.

In addition to the analysis of the professional politics of gender, inquiries into scientific constructions of sex differences resulted in a misogynist portrait of science (Bleier, 1984; Fausto-Sterling, 1985; Hubbard, Henifin, and Fried, 1979). Feminist analysis showed that the construction of sex differences in biology revolves around 'errors of the following sort: (a) the world of human bodies is divided into two kinds, male and female (i.e., by sex); (b) additional (extraphysical) properties are culturally attributed to those bodies (e.g., active/passive, independent/dependent, primary/secondary: read *gender*)' (Keller, 1995a: 87). For example, the process of conception was until recently described as a 'passive egg' waiting for the heroic, active sperm (Martin, 1991). According to Ruth Hubbard, we find manifold versions of the 'sociobiologist's claim that some of the sex differences in social behavior that exist in our society (for example, aggressiveness, competitiveness, and dominance among men; coyness, nurturance, and submissiveness among women) are human universals that have existed in all times and cultures' (1988: 8).

The so-called 'objective' knowledge of male experts was also radically challenged by critical practices in the women's movement. For example, the famous workshop on 'women and their bodies', held in Boston in 1969, promoted alternative forms of health care. The workshop group continued to meet and compile information about women's bodies and health care. Their discussion papers were assembled and published in 1970 as the first version of *Our Bodies, Ourselves;* in the last thirty years, OBOS has been translated and adapted to many different cultures all around the world (Davis, 2002). Challenging men's expertise 'was an extension of this recognition of the power of scientific ideas to define women's sense of bodily awareness, sense of self and sense of reality that propelled the feminist analysis of science to investigate the historical emergence of particular constructions of women and the natural within scientific discourse' (McNeil and Franklin, 1991: 134).

In addition to the women's movement, other social movements, such as the Radical Science Movement in Britain, the anti-war movement, and the ecology movement, contributed to questioning the privileged status of scientific knowledge. The battles against reproductive technologies, biotechnological products, bio-piracy, the Human Genome Diversity Project, and the patenting of living beings have helped to question technoscientific practices. At the same time, they demonstrated their growing impact on everyday life. In view of ecological disasters caused by industrialization, ecofeminism and radical feminism criticized the Anglo-American understanding of nature as the 'Other', as feminine, inferior, and uncanny, that has to be controlled by an autonomous subject (a White man). They fostered the insight that nature should not be reduced to a resource and passive material for men's ends, but regarded as an active agent endowed with its own logic. As many critics pointed out, the hybridization of science, technology, the military, industry, and politics in the last decades also helped to undermine the understanding of science as the only legitimate producer of knowledge. These movements questioned so-called truths 'discovered' by science about the nature of nature, of woman, and of sex.

The growing interest in science and technology studies is partly attributable to the deconstruction of the grand narratives of progress, scientific truth, and objectivity. It also made technoscience a promising field for women's and gender studies. But the challenge to positivism and the rise of the social construction perspective are not due only to the radical critique of the practices and discourses of technoscience by feminists and 'other Others'. They are also related to changes in the theoretical premises in science and technology which formed the basis for the emergence of new technosciences. Wave/particle duality in quantum physics is probably the most famous example for challenging objectivity through scientific theories and practices. Haraway (1985; 1991), Katherine Hayles (1999), and others have analyzed the departure from the classical Cartesian heritage, with its dualism of observer and observed, subject and object, body and mind, towards constructivist epistemologies and 'posthuman' concepts of cybernetics, artificial intelligence, immunology, and brain research. In view of the decline of classical scientific values, feminism strengthened the insight that trying to speak for nature—to interpret its own logic—always involves a politics of representation implying epistemological, ontological, and thereby political claims. Challenging the scientific and technological discourses of truth, feminism argued that nature, sex, and biology are not given nor are they beyond representation, rather they are agents in a high-stakes game, a dynamic relationship as well as a product, constructed and taking part in, or even constructing discourses and practices. The so-called 'natural laws' and empirical data of technoscience were reinterpreted as the outcome of cultural practices with many different human as well as non-human actors. At present, feminist and other critical science studies ask how and for whom knowledge, technologies, agents, and hybrids have been employed so far and continue to be employed:[6]

> with the hope that the technologies for establishing what may count as the case about the world may be rebuilt to bring the technical and the political back into realignment so that questions about possible livable worlds lie visibly at the heart of our best science. (Haraway, 1997: 39; my emphasis)

Feminist approaches reflect on the need for political reflexivity in theory, which is often neglected in mainstream science and technology studies. At the heart of feminist studies lies the search for better, or at least more visible, ways to design and use categories, knowledge, and technologies, to shape objects, artifacts, and worlds in order to make exclusions visible and to overcome the hardships of gender-asymmetries, reductionism, and injustice.[7]

In sum, the critique of positivism and naturalist rhetorics became possible through many different factors: the liberal feminist critique of an unfair and misogynist science, the ecofeminist critique of Western hyperproduction, social movements challenging the privileged status of science, and the postmodern critique of ventriloquial politics of representation. Posthumanist reconfigurations of so-called natural entities like nature, sex, and body also made visible the changed epistemological and ontological groundings of science, which were induced by critical as well as technoscientific discourses and practices. The merging of science and technology, as well as that of technoscience, industry, and politics, all raise questions about the idea of technological determinism.

In the following sections, I will map out movements of denaturalization, dematerialization, and renaturalization in constructionist technoscience and contemporary feminist science and technology studies.

The merging of boundaries between nature/culture (*Denaturalizing nature*), sex/gender (*Constructing sex and gender*), and science/technology/society (*Technoscience*) are at the heart of the current epistemological and ontological reconfigurations of our age. Cultural studies of science and technology (*Technoscience as cultural practice and practical culture*) can be seen as an answer to the new epistemological and ontological challenges induced by technoscientific developments. I conclude with conditions of knowledge production (*The reorganization of knowledge cultures in a messy global world*) and make suggestions for future directions.

DENATURALIZING NATURE: CONSTRUCTIONISM IN CONTEMPORARY TECHNOSCIENCE(S)

Major concepts, such as nature, matter, and body, are profoundly refigured in contemporary technosciences. With the rise of system theory, cyberscience, and new life sciences, there is a move towards the molecularization of matter, breaking up organisms or cells into micro-parts down to the subatomic level (Kay, 1996). This miniaturization enabled 'the translation of the world into a problem of coding, a search for a common language . . . and all heterogeneity can be submitted to disassembly, reassembly, investment, and exchange'. Information becomes 'just that kind of quantifiable element . . . which allows universal translation' (Haraway, 1985: 164).

Technosciences nowadays do not see themselves as primarily engaged in subjugating nature and its processes through creating artificial natures via technological artifacts and systems, but through designing and engineering nature in the sense of reshaping and improving it. 'The claim of technoscience not to create but to continue the work of nature by rebuilding, converting and perfecting it, gives the border between nature and culture its chimerical character' (Weber, 1999: 470). Nature becomes a toolkit and the world a realm of endless possibilities of recombination—with evolution tinkering around to find new ways of development and investment (see, among others, Jacob, 1977). Similar to this logic, organisms are not regarded as something static and given, but as evolving, parallel, and distributed networks, that is a 'fast, responsive, flexible and self-organizing system capable of constantly reinventing itself, sometimes in new and surprising ways' (Hayles, 1999: 158). Attention is given to the creation of spontaneous entities and the logic of emergent behavior. In other words, a constructionist understanding of nature, organisms, and even sex can be found not only in critical feminist theory but also in contemporary technosciences.

Engineering nature makes technoscientific practices even more efficient (Haraway, 1997). This approach relies on a constructionist stance—which implies radical changes in the understanding of science and nature in general. While modern scientific theories linked women and nature, under the assumption that they were both immutable, the refigured posthuman body departs from these essentialist and naturalizing premises. The body is no longer considered as 'natural' and 'given' in the sense of static, unchangeable, and governed by teleological and harmonious principles. With this move, the radical feminist and other critiques of the naturalist or essentialist grounding of the natural sciences became partly obsolete.

This new denaturalization notwithstanding, there has been a strong movement of renaturalization emerging in the rhetorics of popular science, technosciences, and popular culture at the same time. Spontaneity, change, and dynamics are often reinterpreted as natural, evident, and given by 'Mother Nature'. The French molecular biologist François Jacob describes organisms as 'historical structures: literally creations of history. They present not a perfect product of engineering, but a patchwork of odd sets pieced together when and wherever opportunities arose. For *the opportunism of natural selection . . . reflects the very nature of a historical process full of contingency*' (Jacob, 1977: 1166, my emphasis). After all, it seems to be 'Mother Nature' which rendered organisms as patchwork creations via natural selection. The change of ontological and epistemological groundings in the technosciences is made invisible by declaring the turbulent, evolving body not as an effect of the change of paradigm in (techno)science but as natural.

CONSTRUCTING SEX AND GENDER IN THE AGE OF REPROGENETICS AND SEX-CHANGE SURGERY

Given the centrality of gender for feminist scholarship in general, science and technology studies are concerned with how 'gendered artifacts may constitute the glue that sometimes keeps gender relations stable, sometimes on the move' (Berg and Lie, 1995: 346). These studies ask how gender, understood as a product of diverse material, symbolic, and sociopolitical processes 'was at stake in key reconfigurations of knowledge and practice that constituted modern science' (Haraway, 1997: 27). Feminist scholars are 'particularly interested in the question how scientists have constructed "woman" as a natural category' (Oudshoorn, 1996: 123).

What is the meaning of categories like 'woman', 'sex', or 'gender'? Thinking about the category of gender highlights the performative character of feminist theory and science studies, which are themselves a cultural practice and as such are entangled in language games, sociopolitical experiences, and values. One can understand sex/gender as a 'boundary object' (Bowker and Star, 1999), as a classification system which holds together a globalized but predominantly Anglo-American feminist discourse. The differentiation of sex and gender which pervades many feminist discourses in different languages shapes theoretical frames, perspectives, and questions. It is a historical and situated classification which produces a segmentation of the world which fosters strict differentiations between the social and the biological.[8]

The suspicion that every possible differentiation between biology and society, nature, and culture in feminist theories, too, only prolongs dubious definitions of the natural and reifies old normative descriptions of 'woman' might be only the flip side of difficulties in mediating the social and the biological.[9] Sometimes these fears result in a hyperproductive stance, whereby a dogmatic denaturalization of gender and the body turns into their dematerialization. In this conceptual frame of idealism, matter or bodies are conceptualized as the exclusive product of history, society, or discourse. Trying to overcome the dual sex/gender system and the separation of the biological and social often leads to an ignorance or even negation of material, bodily aspects.

While contemporary postmodern approaches favored denaturalization and even dematerialization of the gendered body, they often ignored the strong development towards construction and denaturalization in technoscience itself. Many sociotechnical developments already undermine the dual sex/gender system and the natural in a more profound way than many postmodern theorists had ever dreamed of: new reproduction technologies, cosmetic surgery, and sex-change procedures are radically denaturalizing (and sometimes renaturalizing) the category of sex (Stone, 1993; Stryker, 2000). For example, with the possibility of sex change in the second half of the twentieth century sex becomes—at least in principle—an open, free-floating category.[10]

Technoscientific practices and artifacts such as reconstructive surgery and hormones render radical physical sex change possible. Thus the dual sex/gender system is destabilized by making it (at least theoretically) a matter of technological investigation and individual choice in Western societies.

The denaturalization of bodies is the ontological ground which makes it possible to think of bodies as a toolkit, breaking them down into small parts and reorganizing them in technoscientific practices. Bodies are fragmented into different functions, organs, cells, molecules, genes. A case in point is collaborative reproduction, in which body parts from different, sometimes anonymous donors are made to fit together in the laboratory. The laboratory product—an artificially fertilized egg—is subsequently implanted in a woman, who is not necessarily the child's genetic mother. Collaborative reproduction becomes possible by the separation of sex, sexuality, reproduction, and kinship through which new complex relations of social and biological kinship emerge. These denaturalizing technoscientific practices also produce new social and economic relations in the process of reproduction. But these new practices of reproduction are made invisible at the same time by renaturalizing rhetorics of 'blood ties' and the right to a 'child of one's own'.[11]

TECHNOSCIENCE: A NEW UNDERSTANDING OF SCIENCE AND TECHNOLOGY

With the growing interest in technoscience, we find more feminist science studies which try to mediate de/constructionist with materialist and realist positions. They share central epistemological and ontological premises, like commitment to self-reflexivity, contextuality of knowledge, and interest in empowerment. They reflect on 'standardization and local experience, (on) that which is between the categories, yet in relationship to them' (Star, 1991: 39). They are projects of political intervention and critique highlighted processes of domination and resistance. The goal is to enable empowerment, particularly of those who do not fit the standard or who are on the margins of the production of knowledge and culture.

While earlier approaches in the 1970s and 1980s[12] mainly investigated the social and political conditions of science (often using a 'classical' concept of society), the separation of science and society is now being challenged, along with other separations such as 'science and politics . . . or science and culture. At the very least, one such category cannot be used to explain the other, and neither can be reduced to the status of context for the other' (Haraway, 1997: 62). These challenges are due to fundamental dissolutions of borders between the ontological realms of science, technology, industry, and society and the refiguring of central epistemological concepts. At present, we are experiencing a changed understanding of technology not only in theory, but in the emerging technosciences themselves, which materializes in concrete sociotechnical changes.

In pre-modern societies, technology was understood mostly in the sense of human knowledge, while in modernity, technology's most important connotation was that of the artifact. Today, the contemporary dimension of technology as system and process becomes more and more important. Technological systems are regarded as networks with tightening connections and an organization of material and non-material components which rely on scientific knowledge, engineers, and juridical, economic, and other agents (Hughes, 1986). This new perspective makes visible the 'seamless web' of science, technology, society, industry. Strict distinctions between the socio-cultural and the technical are no longer plausible. In addition, the differences between nature and culture are undermined by technosciences which conduct their research mainly in the laboratory as they construct the nature they are investigating.

The term 'technoscience' marks the merging of science, technology, industry, and the military, as well as the intensified amalgamation of science and technology, of society fusing with the technological, and of a new efficiency in industrial technologies which refigures the organic in a new and most efficient way. These developments are accompanied by radical changes in the ontological premises of (techno)sciences as well as some of their rhetorical strategies and politics of representation (Weber, 1999; 2003). With these multifaceted changes, new epistemologies and methodologies arise which stress the constructionist character of categories such as science, technology, and society.

TECHNOSCIENCE AS CULTURAL PRACTICE AND PRACTICAL CULTURE

With the hybridization of science, technology, industry, and society, it becomes much easier to acknowledge that science and technology, deeply intermeshed in culture, are central sites for the production of ideology. It also becomes easier to grant oneself the right to intervene: 'we have a right, and in fact a duty, to debate, contest, modify and perhaps even to transform' (Balsamo, 1998: 294). Even if we are not trained and socialized in technosciences and even if we are not part of that community of knowledge producers, we are, nevertheless, required to reflect on technoscientific developments which are shaping our world in profound ways.

Today, hybrids, artifacts, and cyborgs populate feminist theories and narratives. There has been a shift within and outside many disciplines (sociology, cultural studies, art, philosophy, literature, anthropology) towards analyzing discourses and practices of technoscience and its growing impact on everyday life. While early approaches in feminist science and technology studies mainly focused on classical sciences, it is now the so-called technosciences—artificial intelligence, biotechnology, neurosciences—which are at the center of feminist scholars' attention. Now that science and technology have been identified as deeply interwoven with many other ontological realms, they are understood as 'cultural practice and practical culture' (Haraway, 1997: 66). Culture is understood as a social practice, as an always situated, heterogeneous, and complex process in which many different agents like concepts, machines, humans, and animals produce meanings and thereby maintain or refigure cultural boundaries.

With this perspective, it becomes much easier to develop approaches which go beyond either the euphoric affirmation of science and technology or their abstract negation. Feminist science studies scholars now want to challenge boundaries and to refigure concepts and frames of thought by inventing powerful stories and different socio-material practices. To strive for more livable worlds beyond the hegemonic tales of progress, of technoscience as biological, and technological determination means also to reinterpret what counts as nature, as sex, or as gender. The central premises of recent feminist science and technology studies are that science and culture are deeply interwoven, that facts are theory-laden, and that theories are not neutral but can better be seen as stories. There are close linkages between metaphors and factuality, between semiotic and material processes. The relationships between science, technology, knowledge, and society are increasingly viewed as open and dynamic.

Intervention into semiotic–material configurations of humans, non-humans, and machines is now seen as not only a possible but a necessary political practice.[13]

THE REORGANIZATION OF KNOWLEDGE CULTURES IN A MESSY GLOBALIZED WORLD

Contemporary science and technology studies use theories and methods from very divergent disciplines and prefer no unified methodology. Inter- or transdisciplinarity is grounded in a radical challenge of the popular idea of two separate cultures of 'hard' and 'soft' science, which was introduced by Charles Percy Snow (1959) and was revived in the science wars in the 1990s:

> The current 'two cultures' discourse assumes a division of labor: humanities researchers are critics who write commentaries on art and ideas, while scientists, engineers, and physicians find out facts about the real world and fix real problems. More succinctly, the humanities are for reflection and the sciences are for investigation. . .[C]ultural studies of science, technology, and medicine violate this division of labor and violate our conventions of expertise. (Reid and Traweek, 2000: 7)

With the breakdown of borders between science and society, between nature and culture, and with the understanding of science as a cultural practice, it becomes more and more obvious that all sciences are determined by cultural values, language games, and politics of representation. Moreover, these values and ideas cannot be categorized in terms of different cultures of knowledge. They travel between different disciplines, realms, and discourses. Take, for example, the notable metamorphosis of system theory in the twentieth century. Starting with biology, it went on to become a central part of cybernetics and molecular biology, and later an important approach in the social sciences, especially sociology. Other frequent transdisciplinary travelers are the concepts of network, emergence, and cyborg, which lose and gain new connotations, change shape, and transport frames of meanings.

The (re)naissance of inter-/transdisciplinarity today seems due not only to developments in critical theory, but also to the floating of concepts and frames of meanings between the disciplines. While transdisciplinary exchange between cultures of knowledge has not been unknown to modern science, I would claim that this exchange rapidly increased with the emergence of technosciences in the post-World War II period. It might be an irony of history that exactly at the time when Snow complained about the advancing gap between scientists, intellectuals, and the public because of the specialization of science and technology, an advancing exchange emerged between scientists and intellectuals in new (techno)scientific fields. Many technoscientists had the feeling that the classical approaches could not provide answers to new demands and questions. Therefore they started to work transdisciplinarily out of a need for new methods and conceptional frames. For example, the transdisciplinary field of cybernetics or, as Evelyn Fox Keller calls it, cyberscience 'was developed to deal with the messy complexity of the postmodern world' (1995b: 85). This might be true as well for other research fields like molecular biology, immunology, and others.

Science studies scholars Egon Becker and Thomas Wehling stress that the transfer of concepts became a 'central element of the dynamic of science and of theories' since the 1950s (1993: 42; my translation). But the effects of these transfers had not been analyzed within the disciplines themselves. Since the 1990s several feminist science studies scholars have reconstructed the transfer of metaphors and concepts throughout divergent disciplines. For example, Lily Kay (1999) analyzed the use of linguistic metaphors and concepts in the life sciences; Elvira Scheich (1993) has shown the major impact of system theory on the social sciences. Crossing the borders between different disciplines, between the so-called hard and soft sciences, seems to be much more common than scientists and intellectuals in either 'culture' realized.

It is my contention that the intensified permeability of the borders of disciplines is linked to recent transformations in science, technology, and society. By this, I mean the reorganization of the cultures of knowledges in our globalized world. I will not draw here on the new organization of knowledge through education policy, restructuring of academic fields, and redistribution of resources (infrastructure, funding, and so on) in the context of multifaceted processes of globalization. What I want to stress here is that knowledge is restructured not along disciplines but primarily along certain theoretical fault lines. Mainstream research areas are currently operating at a level of metalanguage, that is formal systems and models. They succeed in making divergent objects compatible through a contemporary logic of translation and coding which abstracts from material aspects of these objects (Knapp, 1998: 49).

System theory is a good example of this move as is the already-mentioned dominant concept of information in cyberscience, which has been conceptualized as a quantifiable element beyond materiality and meaning thereby allowing universal translation. The decontextualization of knowledge allows the development of powerful theorems that can be applied to nearly every field and context, regardless of their contextual meaning and material grounding. The logic of universal translation is especially attractive in a global world where compatibility becomes a central value. These formal approaches also support the invisibility of political hierarchies and economic injustices—not the least between North and South, West and East.

Today successful fields of research (in terms of funding) are those that follow these new cognitive and epistemological premises. Others that are unable or unwilling to do so often lack funding and, therefore, many so-called old-fashioned academic institutes have closed down. This development might give some clues as to why such divergent disciplines as microbiology, bioethics, and robotics are advancing fields, while disciplines like zoology, philosophy of history, or botany are on the decline.

The reorganization of cultures of knowledge is not only shaped by processes of transnational capitalism and reorganized along theoretical fault lines, but also the outcome of new questions and objects of study emerging in a globalized word. As feminist science studies recognize the reorganization of knowledge cultures, I think it becomes a necessity to focus not only on the production of artifacts and practices but also on hegemonies of cognitive and epistemological frames of thought. Up to now we have no or only a few studies on the contemporary epistemology in terms of hegemonic styles and frames of thought (Foucault, 1970).

FUTURE DIRECTIONS

> After all, in the present world 'after modernity,' there is much to learn and much to do. To be sure, in a climate of polemics, thoughtful interdisciplinary reflection is hard to come by. (Reid and Traweek, 2000: 15)

Keeping in mind recent epistemological and ontological shifts in the age of technoscience, the emergence of posthuman bodies, nature(s), gender(s) as well as the reorganization of knowledge cultures, I want to make some suggestions concerning future directions for feminist studies.

Feminist science studies scholars analyzing transdisciplinary cultures of knowledge should not only be aware of the multifaceted transfer of concepts, methods, frames, and theories, but also adapt these insights to their own analysis. Reflecting on one's own conceptual frame requires at the very least a kind of second-order reflection that keeps in mind that theory itself is imprinted by the traveling concepts, epistemological approaches, and visual and rhetoric practices of the technosciences being analyzed. Thus, the critique of the discourses and practices of technosciences should question its own ontological and epistemological groundings and its entanglement with our technoculture. It is my hope that this kind of second-order reflection will enable alternative research which moves beyond euphoric celebrations of the most recent concepts and ideas from the technosciences as well as pessimistic and abstract negation of the so-called 'other' culture of technoscience—a stance that predominated gender studies for such a long time. Perhaps such a second-order reflection could also foster a critical usage of semiotic–material fields linked to the technosciences, which were so long imagined as the 'Other', as alien and rejected in the abstract. If feminist science and other critical studies succeed in showing the intensified blurring of the science and culture, it could help to overcome old dichotomies of euphoric affirmation of technology or its pessimistic refusal.

In my view, it is quite important that feminist studies continue to elaborate that *the technical is the political* for all the divergent fields of science and technology, showing and analyzing the ongoing co-construction of gender, science, and technology. In order to take part in the shaping of contemporary sociotechnical practices and discourses, we need to engage with today's scientific, cultural, and social turbulences, to engage in contests about what counts as nature, intelligible bodies, or efficient machines. To question techno-pragmatic and hegemonic forms of rationality and the dominant logic of efficiency, usability, and common sense, we need to intervene and challenge hierarchical sociotechnical relations by developing new theories of our age of technoscience.

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NOTES

1. ARPANET was the forerunner of the Internet and developed to promote computer networks for military use.
2. See, for example, Rosalind Gill and Keith Grint (1995) and Sandra Harding (1986).
3. In my usage, 'ontology' signifies the assumptions every theory has to make with regard to the existence (of constellations) of things, entities, etc. The core assumptions are contained in the metatheoretical principles. These general principles encompass not only syntactical structures and criteria of critique but ontological options. The last are responsible for what counts as a fact, as being.
4. For the study of gender in science through history, see Londa Schiebinger (2000). Beside women scientists, there were also feminist sociologists (Berg, Cockburn, Wacjman), philosophers (Code, Harding, Longino, Merchant), anthropologists (Lie, Star, Suchman, Traweek), and a few historians (Duden, Schiebinger) who were engaged in the field of critical science and technology studies in the early days of the second women's movement.
5. For an overview, see Schiebinger (1989) and Renate Tobies (2001).
6. See Haraway (1985; 1997), Harding (1986) Susan Leigh Star (1991), and Lucy Suchman (1987).
7. See, for example, Lorraine Code (1987), Haraway (1988), Nancy Hartsock (1983), Helen Longino (1990), and Hilary Rose (1983).
8. On paradoxes of gender, see also Judith Lorber (1994).
9. See Wendy Cealey Harrison (2006).

10. This choice remains in the dual-sex system and is only given in few countries under strict juridical, medical, and financial restrictions.
11. See, for example, Heidi Hofmann (2003).
12. For example, the Sociology of Scientific Knowledge (SSK) and, respectively, the 'Strong Programme' of the Edinburgh School, ecofeminism, or radical/cultural feminism.
13. See, for example, Haraway (1997) and Reid and Traweek (2000).

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CHAPTER 33

Eco/Feminism and Rewriting the Ending of Feminism: From the Chipko Movement to Clayoquot Sound

Niamh Moore

FROM THE CHIPKO MOVEMENT TO CLAYOQUOT SOUND AND BACK AGAIN I

In the summer of 1993 a local environmental group organised a peace camp to support the blockading of logging roads in Clayoquot Sound, on Vancouver Island, British Columbia in Canada, as part of ongoing campaigning against clear-cut logging of temperate rainforest.[1] The campaign by the Friends of Clayoquot Sound (the Friends) brought an unanticipated and unprecedented 12,000 people to the camp. Many took part in the workshops on nonviolence and civil disobedience offered daily at the camp, before participating in the blockade of the logging road the following morning. By the time the camp closed at the end of the summer, over 800 people had been arrested following the symbolic blockades. In the mass trials which followed all were found guilty and many received jail sentences. The camp which supported these blockades was said to be based on 'feminist' principles, and sometimes these were even explicitly articulated as 'ecofeminist' principles. The slippage between these terms suggests some of the tensions which form the context for this article.

I was at the camp and the blockades in 1993 and returned to Clayoquot in 1996 to carry out research, because the campaign offered a fertile site through which to examine a whole range of issues of ongoing concern for eco/feminism (see Moore, 2003, 2007, 2008a, 2008b, 2008c).[2] I was struck by the vibrancy of the campaign, but also by the difficulty and challenge of bringing what was happening in Clayoquot into conversation with key debates in feminism. There was, for instance, the stark contrast between the prevailing narratives, in the early 1990s and since, of the end—or death—of feminism, and the generative politics of Clayoquot, and eco/feminism more generally. Similarly, despite common assumptions about eco/feminism's essentialism, often understood as manifest through maternalist discourses, there was little evidence of this at the camp (and interestingly, the camp was mixed, not women-only). Indeed, essentialism seemed to offer a very limited way of understanding the politics of Clayoquot. Moreover, and importantly for the focus of this article, in the context of critiques of white Western feminism for being imperialist, colonialist, ethnocentric, racist, universalising, homogenising, and romanticising, eco/feminism's commitment to insisting on the international, also manifest in a number of ways at Clayoquot, countered prevailing trends in feminism away from claims of global sisterhood. One of my ongoing fascinations is the paradox of the sheer vitality of this eco/feminist activism, and its insistence on international connections, in contrast to the widely circulating accounts of the end of feminism, and especially the end of global sisterhood, which emerged in the 1990s. Thus this article is also about how histories of eco/feminism, including tensions between theory and activism, are narrated.

I take as a particular departure point for my explorations here, a moment from an interview with Fireweed (Fireweed, interview, 14 July 1996), when she told me about a conference that she had recently attended.[3] At the conference, Valerie Langer, one of the directors of the Friends, stood up following a talk from Vandana Shiva, and told Shiva that the work of the Chipko movement was being continued in Clayoquot.[4] Shiva's account of Chipko as a women's movement which formed spontaneously to protest commercial logging in the Garwhal Himalayas by hugging trees, has been compelling for many, though is also not without its detractors (Moore, 2008c; Shiva, 1988).

The reference by Langer to the Chipko movement was not the only moment when Chipko was publicly invoked in connection with Clayoquot. The award-winning documentary, *Fury for the Sound: The Women at Clayoquot*, was widely shown on Canadian television, and opens with a clip of Shiva (Wine, 1997). There were no doubt other references to Chipko in the many conversations and writings about the campaign. This mention of Chipko was not unusual or idiosyncratic: by the early 1990s Chipko had arguably become the iconic reference and exemplary, inspirational tale of many eco/feminist books. Yet, very quickly, the celebration of Chipko in many academic eco/feminist texts waned, to be replaced by considerable efforts to demonstrate recognition of, and distance from, the problems of repeated invocations of the Chipko movement which were understood as manifesting particularly difficult versions of essentialism: that of universalising women–nature relationships, of homogenising 'Third World women', of cultural appropriation, of the idealisation of indigenous knowledges and subsistence living. Understanding this rapid shift requires attention to ongoing debates in feminism.

In the context of controversies in eco/feminism over difference, race and the international, it has become difficult to read Langer's claim that the work of the Chipko movement was being carried on in Clayoquot, and its approving repetition by Fireweed, as anything other than yet more evidence of eco/feminism's ongoing and persistent essentialism, universalism, racism, neo-colonialism, imperialism, romanticisation of subsistence practices, ignorance, naiveté, and so on. However, this is precisely what I attempt in this article. I pose a number of questions: how has it become so easy to produce and proliferate such definitive truths about eco/feminism, about Shiva, and the Chipko movement, and the international more generally, to the exclusion of other stories? What work have such characterisations done? What purposes have they served? What have been the, possibly unintended, consequences of such accounts? How could Langer's statement be read differently and what would the implications of this be?

In opening up the possibilities for understanding Langer's claim, I trace what was at stake in various manifestations of eco/feminism at the time and since, with a particular focus on the international. In taking this approach, I do not intend to produce a definitive account of what eco/feminism is, or was then. Rather, echoing Noël Sturgeon's (1997) genealogical approach to eco/feminism, I develop my own necessarily and intentionally partial account.[5] Through a constant movement back and forth, between the circulation of eco/feminism in texts and in activism, between Chipko and Clayoquot, between the local and the global, between feminism and eco/feminism, and through the friction (cf. Tsing, 2005) produced in these movements, I offer a more generous reading of Langer's statement linking Clayoquot and Chipko, suggesting alternative narratives of the recent eco/feminist past and present.

ECO/FEMINISM AND THE INTERNATIONAL

Celebrating Diversity as International Grassroots Activism

In the emerging and overlapping academic and activist literature in the 1980s and early 1990s, it was common to describe eco/feminism by stressing the diversity of the movement. More specifically, perhaps eco/feminists often pointed to the very impossibility of characterising the movement in any simple way, precisely because of its pluralism. For example, one account from 1994 stated that:

> [e]cofeminism does not lend itself to easy generalisation. It consists of a diversity of positions, and this is reflected in the diversity of voices and modes of expression represented in ecofeminist anthologies. The ecofeminist anthologies, *Reclaim the Earth*, and *Reweaving the World*, and the issues of *Heresies* and *Hypatia* on feminism and ecology include the work of different women from different countries and social situations, and their work does not adhere to a single form or outlook. Poems, art, photographs, fiction, prose, as well as theoretical/philosophical/'academic' works are included. Ecofeminism's diversity is also reflected by its circulation in a variety of arenas, such as academia, grassroots movements, conferences, books, journals, and art. (Carlassare, 1994: 220–221)

This range, of positions, of voices, of forms, and of locations was viewed positively, as suggesting that eco/feminism was not dogmatic and could embrace difference; an important value in feminism in the early 1990s. With such an emphasis on diversity, anthologies and special issues of journals, which allowed for a range of voices and forms, were commonly preferred formats for publications at the time. Yet editors of anthologies still felt the need to point to their omissions as in Judith Plant's introduction: 'This anthology in no way fully represents the wide spectrum of thought that is ecofeminism' (1989: 4). One author even declined an invitation to write a single-authored book, believing that it 'would not do justice to such a multivocal grassroots movement' (Gaard, 1998: 3).

However, despite, or perhaps because of, the prevalence of pluralist discourses, Stephanie Lahar also suggested that this emphasis on diversity could give rise to confusion: '[t]he newness of the movement, the breadth of issues it encompasses, and the diversity of people thinking and writing about ecofeminism have resulted in considerable confusion about what ecofeminism actually is, who ecofeminists are, and what they have to say' (Lahar, 1991: 28). Thus, at the same time as diversity was prized, there was also a sense of the challenge of making sense of a range of forms. While these accounts clearly cherish multiplicity of all kinds in eco/feminism, it was also the case, perhaps in part to deal with this sense of too much variety, that one phenomenon came to be particularly foregrounded, and that was the emergence of grassroots eco/feminist activism in diverse locations, all over the world. This is particularly clear in the introductions to key anthologies such as *Healing the Wounds: The Promise of Ecofeminism* (Plant, 1989), *Reweaving the World: The Emergence of Ecofeminism* (Diamond and Orenstein, 1990), and *Reclaim the Earth: Women Speak out for Life on Earth* (Caldecott and Leland, 1983), all three of which stress the importance of global activism.

For example, Caldecott and Leland stated that 'In many countries all over the world, women are taking an increasingly prominent role in political struggles: in the peace, anti-nuclear, health and ecology movements' (1983: 5) while, for Diamond and Orenstein, the writers and activists in their anthology 'share a multicultural and diversified global vision of healing for life on Earth' (1990: viii). This is stated even more emphatically in Petra Kelly's foreword to *Healing the Wounds*:

> This is a book about global ecological sisterhood! . . . This is not a time for complacency. It is a time for continuing to link arms as sisters—like the women in the Chipko movement in India; like the women at Greenham Common, in England, who are not giving up the struggle against militarisation; like the women of the Western Shosone Indian Nation in Nevada who opposed nuclear testing by encircling the test grounds; like the women in the Pacific struggling for a nuclear-free future to prevent babies being damaged through French atomic bomb tests; like the women in the Krim Region of the Soviet Union demonstrating courageously against a new nuclear power plant. (Plant, 1989: ix–x)

As this extract from Kelly demonstrates, eco/feminism was manifested through the practice of listing places or organisations where eco/feminist activism was understood to be emerging. Introducing eco/feminism by providing a list of the activisms that were invoked to constitute eco/feminism's brief history was widespread in eco/feminist writings of the late 1980s and early 1990s (see, for example, Baker, 1993: 2; Gaard and Gruen, 1993: 1; Mellor, 1997: 50; Merchant, 1992: 184).

In addition to the instances cited by Kelly, this list often also included some of the following: the Kenyan Greenbelt Movement, the Women's Pentagon Actions, the campaign against the Narmada Valley Dams, the Love Canal Homeowners campaign against toxic waste dumping, the women who organised around Chernobyl, Bhopal, nuclear testing in the Pacific, the Women's Environmental Network and many more. Eventually, however, even the list got too much. Following Lahar's observation of the confusion which eco/feminism's diversity seemed to produce, the challenge of trying to hold on to this diversity was too demanding, and one movement ended up being plucked out and held up as the exemplary instance of eco/feminist activism—the Chipko movement. Yet in the context of controversies over difference, race and global sisterhood, eco/feminists faced intense critique, especially from feminists in the field of development studies (see Moore 2008c) and increasingly from eco/feminists themselves.

Eco/Feminist Responses to Critiques of Chipko and the International

Celebratory accounts of the global, and of Chipko in particular, rapidly gave way to more careful reflections. Internal critique sought to address the challenges of cultural appropriation. Such accounts often focus on the anthologies mentioned (both Plant's and Diamond and Orenstein's anthologies contain chapters by Shiva on Chipko, as well as other references to Chipko throughout). Cate Sandilands identified their limitations as such: 'The inclusion of race was not especially analytical; it did not in most cases, suggest ways in which women may have different relations to particular ecological issues or problems, and it did not look deeply at the ways in which these traditions have themselves been lost or reconstructed in particular social contexts' (1999: 54). She elaborated on the characterisation of indigenous cultures as 'somehow pure, somehow dissociable from what colonisation has done to those different cultures and social practices. Also problematic was their general assumption that all "women's" practices in nature are (at their core at least) benign, caring and respectful' (1999: 55). Sandilands concluded her discussion on a relieved note: 'But (I'm very happy to say) this mode of discussion is no longer predominant in ecofeminist literatures that question racism and colonialism' (1999: 56).

Others offer further resolutions to the apparent 'problems' of these texts. One route was to suggest a turn to research on women in the North. Chris Cuomo wrote: '[w]hile there is a tendency in Western ecofeminist theory to describe the work of rural Third World women as paradigmatic ecofeminist activism, one sees little effort (in the literature) to develop specific models that examine the politics of "first world" megaconsumption on ecofeminist grounds' (1998: 8–9). Cuomo's suggestion was taken up and cited by Sherilyn MacGregor in accounting for her own research with women living and working in Ontario, Canada: 'I am making the point that the experiences and ideas of urban-dwelling women in the overdeveloped world are as interesting and informative to ecofeminist thought as those of "peasant" women in developing countries' (2006: 128). A turn to attention to the activism of women in the North is of course understandable—after all I have carried out my own research on Clayoquot Sound. Yet there are possible problems with this strategy. Not least perhaps one unintended effect of this approach is that it risks erasing the references to the movements of the North already commonly mentioned in some of these collections, including Greenham Common, the Seneca Women's Peace Camp, the Women's Pentagon Actions, and the strong anti-toxics movements in the US. Many organisations and actions in the North have focused intensely on (over)consumption.

Such resolutions also risk the implication that (Northern) eco/feminists can have nothing to say on the matter of women and the environment in the Third World. Neither does it suggest then how Third World women can speak and be seen and heard by Northern eco/feminists. Furthermore, such an approach also belies the myriad ways in which North and South are intimately interconnected through the histories of colonialism and slavery, through the movements of goods and the effects of environmental degradation, and through the movements, actual and virtual, of activists. All of this is manifest in the work of many of the organisations mentioned. Some movements such as Women for an Independent and Nuclear Free Pacific are well understood to be alliances between women in the North and South. Thus a shift of focus from the South to the North requires careful attention to the specificities and contexts of histories and transnational connectivities. Questions of race and indigeneity were central in Sturgeon's *Ecofeminist Natures: Race, Gender, Feminist Theory and Political Action*, where she identified the two above-cited anthologies as 'the most prominent representatives of the diversity within ecofeminism' (1997: 116). In focusing on discourses which 'center on the idealisation of "indigenous" women as symbolic representatives of ecofeminism' (1997: 113), she summed up some of the assumptions embedded in such 'uses' of 'indigenous' women: that 'non-industrialised' cultures are seen as more 'ecological', as not manifesting a 'Western' separation of nature and culture, and possibly to embody more egalitarian gender relations (1997: 114).

Yet it is possible to open up some of the critical accounts of the anthologies to further readings. For instance, Plant's reliance on Native American religious rituals (Sturgeon, 1997: 121) is somewhat more complicated when one notes Plant's location in British Columbia in Canada, drawing on 'First Nations' cultures, rather than 'Native American' as such. While not wishing to fuel Canadian exceptionalism, and while also recognising that indigenous peoples of North America do not necessarily accept national boundaries, my point is to draw attention to how this argument may rely on reading a specific and located First Nations iconography as a generalised indigeneity. Plant's ongoing commitment to bioregionalism may also contribute to the intentionality and specificity of her account and the imagery in her text. When the book was published in the UK, perhaps in recognition of the specificity of the indigeneity being invoked, the cover was changed, so that the UK version has a crystal, with light diffracting through the crystal creating a rainbow of colours. Furthermore, critiques of the anthologies have tended to attribute agency to the editors, but with much less attention to the intentionality of the contributors. One is left with the possibility that those women of colour who have contributed to these supposedly essentialising, universalist collections which reproduce problematic indigeneities and racial essentialisms are naïve, essentialist, romanticisers of 'their own' 'indigenous' cultures. How is it possible to make sense of the inclusion of black, Third World and indigenous women who make explicit critiques of these kinds of discourses within some of these texts, not only in terms of the possible desires of the editors to appear inclusive, but also by taking account of their own possible intentions and desires to be included in these volumes, no matter how problematic they might understand them to be?

It is difficult not to notice that from the mid 1990s onward, there were few anthologies published which explicitly identified themselves as eco/feminist. By the mid to late 1990s the practice of creating collective polyvocal texts such as anthologies and special issues of journals, had largely given way to single-authored monographs by mainly white, North American authors. It is also difficult not to wonder if the responses to assumptions of essentialism and universalism had been carefully and empirically worked through. In her final chapter, entitled 'What's in a name', Sturgeon examined the related practices of creating new terms for eco/feminism (such as ecological feminism), and creating typologies of different kinds of eco/feminism (radical ecofeminism, socialist ecofeminism, etc.). This resulted in separating out 'anti-essentialist' and 'essentialist' eco/feminisms, which were mapped onto post-structuralist/academic feminisms and activist and spiritual feminisms (that is, 'good' and 'bad' eco/feminisms). Importantly for my argument, she identified 'two common results of the practice of typologising: the invisibility of women of colour and the creation of a divide between feminist theory and feminist activism' (Sturgeon, 1997: 173), demonstrating how Chipko is doubly disadvantaged in such accounts of eco/feminism. Furthermore, by extending ecofeminism's genealogy, I suggest it is possible to understand the practice of typologising as marking a shift in the way eco/feminism is defined and described, from a commitment to producing eco/feminism's diversity, to the practice of defining eco/feminism through the conceptual binary of essentialism or anti-essentialism. This allowed theoretical pronouncement on eco/feminist activism with little empirical detail, a suggestion also implicit in the introduction to a more recent eco/feminist anthology: 'although it is considerably developed in both popular movements and academic discourse, ecofeminism remains largely a theoretical conversation . . . while there are many grassroots activist women's organisations resisting the negative effects of globalisation, these activities do not provide the primary data for ecofeminist discourse' (Eaton and Lorentzen, 2003: 5). It is with this context in mind that I return to Clayoquot to explore further the campaigning of the Friends as a way into suggesting other possible readings of Langer's statement.

FROM CHIPKO TO CLAYOQUOT AND BACK AGAIN II

What if we held open the possibility of Langer's (and the Friends') extensive knowledges, particularly of the multiple entanglements of the local and the international, rather than assuming essentialism and/or universalism on the basis of a mention of the Chipko movement? Some of this knowledge was visibly manifest in the campaign, in too many ways to enumerate here, but, for instance, it was no accident that I first came across Clayoquot in the office of the Women's Environmental Network (WEN) in London in the summer of 1992. At that time WEN was the only environmental organisation in Europe which had a temperate rainforest campaign. Most other environmental organisations were still focused on the destruction of tropical rainforest. WEN was an initial point of contact for the Friends when they wanted to bring their campaign to Europe, as they followed the path of the trees, now timber and wood pulp, exported from British Columbia. WEN, with its multiple attentions to how women might bear the brunt of some environmental problems, but also to how women in the North are implicated in the overconsumption of disposable paper products which originate, and have environmental (and other) consequences elsewhere, like in British Columbia. Thus WEN's focus on the connections from breast cancer, dioxins, landfill, from toilet roll and sanitary towel, to old growth forest in British Columbia, meets some of the concerns of those such as Cuomo mentioned.

The Friends (along with other British Columbia environmental groups) were also pointing to how the focus on the destruction of tropical rainforest in the Amazon allowed countries like Canada to blame the developing world for overpopulation and destroying rainforests, while at the same time being responsible for incredible environmental destruction at home. The Friends' take-up of the 'Brazil of the North' campaign was indicative of efforts to hold the North to account for the global implications of its activities: 'Canada is the Brazil of the North. Brazil is losing one acre of forest every nine seconds. We're losing one acre every twelve seconds'.[6] Internationally other environmental organisations took up their call, and protests were held outside Canadian embassies around the world, in New York, London, Germany, and Japan, all countries where wood pulp from BC was used to make toilet roll, and newsprint and disposable chopsticks. This attempt to call the Canadian government to account by shaming it internationally did not go unheeded. The Friends were called traitors and accused of treason, so clearly was their message understood by many (if not necessarily by eco/feminist academics anxious about the accusation of essentialism/universalism) (see Moore, 2003).

Global connections also had histories. The relation between forestry and nation building was proudly advertised in the logging company poster with the slogan: 'We came, we sawed, we conquered' (Vidal, 1993: 24). H.R. Macmillan, founder of the company responsible for logging in Clayoquot Sound, travelled to India in 1914 as part of his unusual attention to developing a significant export market for timber from British Columbia. Thus trees from BC made their way to India, where the lumber industry was struggling to meet the demands of British colonists to extend railways across India. But it was not just timber which travelled across borders, but also the nascent field of forestry science, which crisscrossed the world and was tested in British colonies like India and Canada (Drushka, 1995; Tsing, 1997). Much later, Shiva would leave India for Canada, and speak at conferences such as the one where Fireweed heard her speak. I could go on, weaving the webs of connections which are really what is essential to eco/feminism. This process does not so much demand extensive in-depth research, as an openness to alternative stories and knowledges, and a willingness to accept the risk of the accusation of universalism.

My point is that Langer's 'we are carrying on the work of the Chipko movement' cannot even straightforwardly be assimilated into an account of white women's benevolence, philanthropy, or virtue ethics. There was no plan to go to India to help the Chipko women hug trees, or to somehow try to raise 'aid' for the women of the Chipko movement; rather there was a focus on the recognition that women in Canada, in Clayoquot, were implicated in the global trade in trees and timber (and forest science), that appropriate action might not be in India but in fact in one's own backyard (to reverse the accusation of NIMBYism often applied to environmental activists), and that action might be to try to make public the Canadian government's complicity in such global trade and global environmental devastation. There was perhaps also recognition that protesting logging was not necessarily work for Clayoquot's own indigenous peoples, but rather a job for the (other) women who had come to live there, that in fact the work of protecting forests might be part of the 'homework' of living in this place.

Jane Roland Martin has noted that the possibility of accusations of essentialism contributes to a 'chilly research climate' which 'can adversely affect the development of feminist theory and research' (1994: 630–631). The opprobrium attached to universalism, cultural appropriation, and investments in symbolic indigeneity has had similar consequences which have rendered certain topics such as Chipko being abandoned in eco/feminist texts from the mid 1990s onwards, or only mentionable as that from which to demonstrate one's theoretical and conceptual sophistication. Teresa de Lauretis and others have commented on the unintended consequences of the critique of essentialism, and the effects of an insistent anti-essentialism, suggesting that we may need to take the risk of essentialism seriously (De Lauretis, 1989). There has yet to be a similar chorus suggesting that feminists take the risk of universalism or, more precisely, the risk of the *accusation* of universalism seriously, not least because universalism is at best understood as meaning still attached to naïve fantasies of global sisterhood, but more usually understood as a euphemism for racism, and no feminist would want to risk this accusation. Although there is now a trickle of voices on this and a number of prominent feminist scholars have been rethinking the universal, including those such as Judith Butler (Butler, Laclau and Žižek, 2000).

This careful return to the universal has also been recognised recently in a number of texts in a review essay by Denise deCaires Narain:

> But if feminist discourses in the last two decades of the last century were characterised more by what they *don't* share than by what they *do*, very recent work suggests a cautious but steady shift back to ideas of connectedness and solidarity. There are now even a few cagey references to 'universalism', though the confident assertions of 'sisterhood' in Robin Morgan's *Sisterhood is Global* (1984) remain firmly behind us. (2010: 95; emphasis in original)

Any number of black and Third World feminists have continued to work on these matters. Chandra Talpade Mohanty has revisited her original essay 'Under Western Eyes: Feminist Scholarship and Colonial Discourses' (1988), intriguingly entitling the revisioning as '"Under Western Eyes" Revisited: Feminist Solidarity through Anti-Capitalist Struggles', where she speaks, if not of global sisterhood, of solidarity. Mohanty suggests that, while it is hard to discern a women's movement in the US, women's movements are thriving around the world (2003: 221) and re-emphasises the importance of the connections between local and universal (2003: 226).

REWRITING THE ENDING OF FEMINISM

Eco/feminists have not been the only ones to point to the proliferation of feminisms globally. Mary Hawkesworth has also noted the curious coincidence: 'a strange phenomenon has accompanied the unprecedented growth of feminist activism around the globe: the recurrent pronouncement of feminism's death' (2004: 962). Mohanty noted that it had 'become much harder to discern such a women's movement from the United States'—while also suggesting that 'women's movements are thriving around the world' (2003: 221). These glimpses of other stories are suggestive. Accounts which insist on providing evidence of the persistence of international feminist activism might not so much be evidence of a problematic universalism, but precisely the opposite, suggesting 'the end of feminism' and 'the end of global sisterhood' to be universalising narratives which were never true for all feminists or all women. Perhaps certain forms of feminisms ended and certain global sisterhoods were curtailed, but this does not necessarily entail the end of all feminisms.

Echoing Sturgeon's account of typologies, Hawkesworth suggested that '[t]hese textual accounts of death serve as allegorical signs for something else, a means of identifying a perceived danger in need of elimination, a way for a community to define itself through those it symbolically chooses to kill' (2004: 963). The title of a recent conference provoked me to think further about the supposed end of feminism, and specifically the persistent repetition of this narrative. The grammar of the conference title was striking and provocative: *Ending International Feminist Futures? Re-viewing Sex, Gender and International Politics*.[7] Rather than reproducing the 'narrative proclamation' of the end of feminism (Wiegman, 2000: 808) or the obituary of feminism, 'death by report' (Hawkesworth, 2004), the conference title opened up a space to call such declarations into question. It has been clear that the end of feminism has been immediately bound up in arguments about post-feminism, third waves, fourth waves, and generational conflicts, which have always undermined the supposed end of feminism. The use of the gerund in the title, the 'ing' of 'ending', pointed to the constitutive element of these pronouncements: the end of feminism appeared less an 'after the fact' declaration, and more a performative enunciation; death was not by natural causes as Hawkesworth discerned. Yet given the use of the question mark, the title of the conference opened up a host of questions: *are* we ending feminisms through our very declarations?; begging further questions, *why* would we do this? How is the international implicated in the end of feminism? And a further question: what might we now do to prevent such a future, of the end of international feminisms.

At the same time that the repetition of feminism's end might be understood as performative, as bringing about the very demise of feminism, perhaps paradoxically this cacophony of voices suggests the contrary to me. The apparent fascination with endlessly poking the supposed 'corpse' of feminism, perhaps to see if it still moves, if it is not quite dead yet, if there is still life, perversely suggests the continuing vitality of feminism, and an ongoing fascination with and passion about feminism's fate. Despite the seemingly endless repetition, feminists' actual ability to kill off feminism seems limited. It may make sense to think of this repetition of the end of feminism as performative, but not as performing the end of feminism, or even premature burial, but, rather, as a perverse way of keeping feminism alive at a time when (for some) it was not clear what else to do. In contrast, here I am suggesting that eco/feminists' repetition of global activisms offered a hopeful counter-narrative to the end of feminism, involving an active enrolment of the international in efforts to refigure feminist futures.

Attending to what is at stake in different moments in eco/feminism points to the extent to which eco/feminism is bound up in narratives of feminism. Clare Hemmings' work is useful here. She identifies a dominant narrative of the recent feminist past, though one with different inflections: a story of progress and a story of loss of political activism. She demonstrates how both stories rely on fixing certain feminist conversations in specific decades in order to produce an account of feminism as having changed (Hemmings, 2005): the 1970s have been characterised as essentialist, the 1980s recounted as dominated by 'difference' and the race and sex wars, and the 1990s appear as the decade when these differences were transcended, or lost, by poststructuralist feminist theory, depending on which story the narrator wants to tell. Hemmings' account demonstrates why efforts by eco/feminists to produce eco/feminism as anti-essentialist (or only strategically essentialist, in Sturgeon's case) have had limited success. In these accounts, essentialism is transcended not only through the emergence of a sophisticated poststructuralist, anti-essentialist feminist theory, but also by being left behind in the past, in the 1970s, to be precise. Thus not only is eco/feminism (supposedly) essentialist and universalist, but eco/feminism reveals its lack of sophistication through being essentialist and universalist at the wrong time.

Eco/feminism's emergence, while traced to the 1970s (and earlier) is more often located in the 1980s and 1990s, thus exceeding the necessary temporal container of the 1970s for essentialism. The emergence and persistence of eco/feminism, with its supposed essentialism and universalism, in the 1980s and 1990s, threatens to disrupt efforts to produce a progress narrative of feminism which require that essentialism is left safely behind in the 1970s. By the late 1980s and 1990s, eco/feminists should know better. Eco/feminism's insistence on the international and on some version of global sisterhood can be understood then as sheer stupidity or ignorance, or wilful perversity. But I suggest here that it might be possible to understand eco/ feminism's insistence on diversity and the international, less as a naïve throwback to the essentialist 1970s and 1980s, and more as an intentional counter-narrative to stories of the end of feminism and the impossibility of global sisterhood. It is worth noting that, despite critiques, including internal ones, of eco/feminism's account of Chipko, and the international more generally, some writers have persisted in writing on this (Eaton and Lorentzen, 2003; Salleh, 1997, 2009; Silliman and King, 1999; Starhawk, 2002). Yet when Joni Seager writes 'that feminist environmentalism is hot and getting hotter' (Seager, 2003: 945), this too seems like a performative enunciation, though a more hopeful one than the end of feminism. It is not clear that eco/ feminism or even feminist environmentalism is 'hot'—or maybe it is in geography or other domains—but it is not clear that it is in feminism more widely. However, this may be the point: that eco/feminists oriented to mainstream debates in feminism struggle to be heard and taken seriously, precisely because implicit, if not always explicit, in eco/ feminism is a strong critique of prevailing narratives of feminism.

REVISIONING AND RECLAIMING CHIPKO AND CLAYOQUOT

While Sturgeon's genealogy attends to what is at stake in the practice of naming and typologising, here I turn to genealogy to examine the intentional creation of a community of eco/feminists. Such genealogical practices can offer an account of why eco/feminists might need to return to Chipko, to the international, and to fantasies of global sisterhood, as sites which merit genealogical investigation, rather than dismissal. I point to what I understand as a 'tradition' of feminist genealogical practice, and I suggest that Michel Foucault's work on genealogy has been particularly useful for feminists precisely because it articulates well with existing feminist practices. I understand Adrienne Rich's essay 'When We Dead Awaken: Writing as Re-Vision' ([1971] 1979), as genealogical, noting that it was published in the same year as Foucault's essay 'Nietzsche, Genealogy, History'. Tracing genealogy's own genealogy through feminism (rather than exclusively Foucault or Nietzsche) is of course precisely genealogical. Rich wrote, clearly aware of the constitutive power of histories: 'Re-vision—the act of looking back, of seeing with fresh eyes, of entering an old text from a new critical direction—is for women more than a chapter in cultural history: it is an act of survival' ([1971] 1979: 35). Feminists have actively engaged in the project of history making and history writing in order to create collectivities and shared futures.

Other feminists too have also taken up the possibilities of genealogy (Braidotti, 1991: 151; De Lauretis, 1989, 1993). Alison Stone elaborates in her account of Judith Butler's work, whose declared aim in *Gender Trouble* is to outline a '*feminist genealogy* of the category of women' (Butler, 1990, in Stone, 2004: 136):

> I will suggest that women always become women by reworking pre-established cultural interpretations of femininity, so that they become located—together with all other women—within a history of overlapping chains of interpretation. Although women do not share any common understanding or experience of femininity, they nevertheless belong to a distinctive social group in virtue of being situated within this complex history. This rethinking of women as having a genealogy entails a concomitant rethinking of feminist politics as coalitional rather than unified. According to this rethinking, collective feminist activities need not be predicated on any shared set of feminine concerns; rather, they may arise from overlaps and indirect connections between women's diverse historical and cultural situations. I hope that my exploration will begin to show how a genealogical rethinking of women could enable feminists to oppose (descriptive) essentialism while retaining belief in women as a group with a distinctive, and distinctively oppressive, history—an ongoing history which is an appropriate target of social critique and political transformation. (Stone, 2004: 137)

Reading Chipko in the light of Rich's account of revisioning and those such as Butler and Stone on genealogies of women, it is possible to understand invocations of Chipko differently, and to trace the connections being made between Fireweed, Langer and Shiva/Chipko, not as signalling a universalised essential femininity, but as a genealogy of women, 'as a motivated, and motivating practice' (Haran, in Haran and Moore, 2008: n.p.), as revisioning a community of eco/feminists.

To genealogy as a practice of revisioning we could also add the work of 'reclaiming'. My opening questions echo Isabelle Stengers, who explores 'reclaiming' Shiva's work specifically, against what she terms 'essentialist hunting' (after the witch hunts). She states that the relevant question is 'Can we separate Vandana's force—which produces her ability to struggle—from those seemingly "essentialist" grounds? And the challenge would be learning to . . . hesitate about our own conditions of thought' (2008: 41–42). Drawing on the work of US Wiccan witch and eco/

feminist Starhawk (who came to Clayoquot and was arrested), Stengers expands on Starhawk's practice of reclaiming, and its capacity to make us hesitate:

> Reclaiming is an adventure, both empirical and pragmatic, because it does not primarily mean taking back what was confiscated, but rather learning what it takes to inhabit again what was devastated. Reclaiming indeed associates irreducibly 'to heal', 'to reappropriate', 'to learn/teach again', 'to struggle', to 'become able to restore life where it was poisoned', and it demands that we learn how to do it for each zone of devastation, each zone of the earth, of our collective practices and of our experience. (2008: 58)

These kinds of understanding of genealogical practices are also suggested by Anna Lowenhaupt Tsing's work, which is useful not least because of its focus on the destruction of forests in Indonesia. In *Friction: An Ethnography of Global Connection*, Tsing explores global connections and 'practical, engaged universality as a guide to the yearnings and nightmares of our times' (2005: 1). She writes that '[a]s soon as we let go of the universal as a self-fulfilling abstract truth, we must become embroiled in specific situations' (2005: 1–2). One of Tsing's interests is collaborations between environmentalists and indigenous peoples, and obstructions to such collaborations. She notes those who understand environmentalists' interest in indigenous knowledge 'only as a repetition of metropolitan fantasies and imperial histories' (2005: 161). Her concern is that such accounts 'offer a historical metanarrative of imperial modernisation in which nothing good can happen—good or bad—but more of the same. Familiar heroes and villains are again arrayed on the same battlefield. It is difficult to see how new actors and arguments might ever emerge' (2005: 161). Though Tsing's concerns are not explicitly about feminism (or eco/feminism), she does reference Sturgeon's anxieties about eco/feminist appropriations of indigenous cultures here (2005: 159–160). However, Tsing's use of 'friction' not to signal a repetition of a 'clash of cultures' but to gesture to 'the awkward, unequal, unstable, and creative qualities of interconnections across difference' (2005: 4) is a welcome contribution to efforts to rethink connection and solidarity.

I suggest that it is no accident that it was eco/feminists who insisted on articulating a politics of global connection at a time when many feminists were disinvesting in such politics. While white feminists were confronting the challenges of black and Third World women, the 1980s and 1990s were a point when environmentalists were successfully challenging the relevance of national boundaries for containing environmental problems, and insisting that solutions to environmental problems also required international mediations. Similarly, the environmental movement and environmental activists were recognising the need for activism which transcended national boundaries.

I am also taken with Tsing's turn to the practice of list-making in her discussion of collaborations and specifically of biodiversity assessment as a multicultural exercise. At the insistence of one of her friends and mentors in the Meratus Mountains in Indonesia, together they made a list of all the plants and animals on Borneo. Noting the importance of species lists in making conservation claims, and recognising how these lists enable 'us to discover variety and to appreciate dynamics', Tsing offers her list as 'a motivated set of translations and not a simple addition to either universal or local knowledge culture' (2005: 162). She reflects that '[l]istmaking is eclectic to the extent that it draws on multiple, fragmentary sources. To acknowledge this eclecticism allows us to admire its creative use of limited materials, rather than to grasp only for scope. It allows us to imagine the list within historically changing conversations, rather than as transcendental knowledge' (2005: 162). This account of list-making is profoundly genealogical.

An account of list-making as a knowledge practice is instructive in revisioning and reclaiming eco/feminists' lists of activism, suggesting ways of reading such lists, not as essentialist or universalist, but rather as linked specificities. This way of introducing eco/feminism performed a number of different functions. These lists provided an introduction to eco/feminism in the absence of any agreed definition of the term. They offered a way of describing eco/feminism without having recourse to generalisations to which there would have been far too many exceptions. The examples cited hinted at the complexity and diversity of women's relationships with nature and their environments. These examples were important not just because they illustrated what eco/feminism was about—connections between the oppression of women and the domination of nature—but also because they illustrated that there was no *one* eco/feminism. These people and places were offered up as evidence that eco/feminism did not just happen in the imaginations of some feminist academics dreaming up some real community involvement. In the changing context of anxiety about the essentialisms of activism and the universalisms of fantasies of global sisterhood, the diverse locations of these actions and practices were as significant as the actions themselves, offering a counter-narrative to the end of global sisterhood and the end of feminism. The diversity initially valorised by eco/feminists was not only activism, not only international activism, but was also a diversity of forms, as is clear from the account by Carlassare earlier in this article, and from attention to the introductions to the anthologies. Diverse genres, forms of knowledge and knowledge practices, were included. In focusing anxiety on the preponderance of Third World activism and Native American spiritualities, this attention has been lost.

Constructing lists and genealogies offers a different knowledge practice to some of the other possibilities available. Against the deadening repetition of the end of feminism, against the typologies of eco/feminism which sought to purify theories of essentialism and activism, and against the progress narratives of certain feminist histories, others were briefly, excitedly, repeating the names of places around the world, and passing these on to each other, not as a universal, essentialised womanhood, but more as an insistence on what needed to be done, an invocation to action. I understand this practice of listing eco/feminist activisms as a kind of ritual, a performative recitation, in Butler's sense, which insisted on the persistence of feminist activism, and hoped to bring eco/feminism into being, and at the same time ward off the challenges of those who would deny the possibilities of connection. This list has many beginnings but no one ending. The challenge for eco/feminist academics is to figure out how to articulate ourselves into this community, genealogy, and to figure out what we must do (to) ourselves. The work for eco/feminist academics might yet still be to articulate the complicated, messy tensions, frictions in the unfinished, open-ended listing, genealogy, of eco/feminism, which theorises and enacts, which traces histories, records the present, and conjures imagined communities of eco/feminists, a genealogy that I continue to recite, reclaim and revision:

> . . . the Chipko Movement, the Kenyan Greenbelt Movement, the Women's Pentagon Actions, the campaign against the Narmada Valley Dams, the Love Canal Homeowners campaign against toxic waste dumping, the women who organised around Chernobyl, Bhopal, nuclear testing in the Pacific, Greenham Common, the Women's Environmental Network, Clayoquot Sound . . .

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NOTES

1. For more on this see www.focs.ca, the Clayoquot Archive website (http://web.uvic.ca/clayoquot/clayoquotArchive.html) and Magnusson and Shaw (2003).
2. I use 'eco/feminism' to gesture towards sometimes fruitful, sometimes unproductive, tensions between eco/feminism and feminism, while at times using 'ecofeminism' and 'feminism' to signal to moments when these might be understood to be separate categories. Eco/feminism is both 'of' feminism and offers a critique of it. I hold on to this label of eco/feminism as productive at this juncture in feminism, to signal a specific constellation of interests, which cannot be assumed under the rubric of 'feminism' alone (Moore, 2007).
3. The conference was *Praxis/Nexus: Feminist Methodology, Theory, Community*, at the University of Victoria, Canada (January 1996).
4. Indian scholar and activist Vandana Shiva has been key in bringing the Chipko movement to popular attention and acclaim, initially through *Staying Alive: Women, Ecology and Sustainable Development* (1988) and through her countless talks, conference participation, and activism.
5. There are many other connections that could be traced: to other environmental protests in British Columbia and internationally, such as Redwood Summer in California; as well as other feminist peace camps, like Greenham Common in the UK, and Seneca in the US; to a history of First Nations protests in British Columbia; to connections between the Clayoquot camp and tree-planting camps.
6. The Brazil of the North campaign was initiated by Colleen McCrory of the Valhalla Wilderness Society (for more on this see http://web.uvic.ca/clayoquot/files/volume1/III.D.5.pdf).
7. A version of this article was presented at this conference (October 2008, University of Aberdeen), jointly with Joan Haran (Cardiff University), with the title 'Revisioning Feminism: Imagining Feminist Futures'. Joan's argument turned to a different cultural intervention, that of feminist science fiction, in this way pointing to another commonly disavowed feminism.

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