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Feminist philosophy of science: history, contributions, and challenges

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Abstract Feminist philosophy of science has led to improvements in the practices and products of scientific knowledge-making, and in this way it exemplifies socially relevant philosophy of science. It has also yielded important insights and original research questions for philosophy. Feminist scholarship on science thus presents a worthy thought-model for considering how we might build a more socially relevant philosophy of science—the question posed by the editors of this special issue. In this analysis of the history, contributions, and challenges faced by feminist philosophy of science, I argue that engaged case study work and interdisciplinarity have been central to the success of feminist philosophy of science in producing socially relevant scholarship, and that its future lies in the continued development of robust and dynamic philosophical frameworks for modeling social values in science. Feminist philosophers of science, however, have often encountered marginalization and persistent misunderstandings, challenges that must be addressed within the institutional and intellectual culture of American philosophy.

Keywords Feminist philosophy · Feminist science studies · Gender bias · Women in philosophy · Interdisciplinarity · Case study methodology

Scholars who study gender and science are engaged in a field of inquiry within philosophy of science that is both socially relevant and yields important and original research questions for philosophy. Feminist philosophers of science have worked to advance the status of women in the science professions, to critique and correct sexist science, and to critically evaluate our models of scientific reason and practice in light of the findings of gender studies of science. In doing so, they raise novel philosophical

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issues and extend the reach of philosophy of science to realms outside of philosophy and the academy.

Feminist philosophy of science is a tiny subfield that has been marginalized within philosophy but is extremely influential beyond it, in areas such as feminist science studies, academic feminism in general, and social studies of science. Few outside of feminist philosophy of science fully appreciate the intellectual context and sources that have shaped it, a fact that contributes to misunderstandings of its aims and premises. The first aim of this paper is thus to offer a concise intellectual history of feminist philosophy of science adequate to the scope of its influence and its sources. Briefly tracing its development within the broader context of feminist science studies over four decades, I emphasize the origins of the field among feminist scientists, the critical role that its interrogation of traditional epistemologies has played in developing methodologies and epistemologies for feminist scholarship as a whole, and the interdisciplinarity of its scholarship.

With this intellectual history and context in place, I then examine the contributions of feminist philosophy of science, as well as the challenges its practitioners have faced. Feminist philosophers of science have forged a case-study-based practice that is rooted in interdisciplinary methods, training, and community, and is highly engaged with and influential within contemporary scientific research. Feminist philosophers, however, encounter distinctive challenges in doing this work. Female philosophers, and feminist philosophy, remain marginalized within philosophy. Feminist philosophical work on science meets resistance from those who persist in seeing it as anti-science. Finally, the significance and proper role of feminist philosophy of science is often restricted to the matter of gender bias in science. I address each of these issues in the discussion below.

1 History

Feminist philosophy of science developed within feminist science studies, the multidisciplinary stream of feminist scholarship on gender and science that began in the 1960s. The field is institutionally and intellectually rooted in academic feminism. To begin a discussion of the contributions of feminist philosophy of science without appropriately situating it in the history of feminist scholarship on the sciences would be to artificially constitute it as an independent line of knowledge production or merely a subfield of philosophy of science, and thereby to fail to appreciate its institutional-intellectual context and sources. A historical retrospective of the field of feminist science studies provides essential context for understanding the central claims and debates in feminist philosophy of science, as well as motivation for the critical discussion of the contributions and challenges of feminist philosophy of science that follows.[1]

[1] It is common to situate feminist science studies within the intellectual transformation of the American academy following Kuhn, the influx of women and minorities into American universities, and the advent of poststructuralism—a period characterized by Peter Novick (1988) as "objectivity in crisis." The Novickian view that, after Kuhn, academia fractured into an impenetrable array of epistemological and anti-epistemological stances is strikingly common, and impedes constructive discussion about the aims and impacts of

In this review of four decades of feminist science studies, I focus not on leading figures or the internal progress of ideas, but on a particular kind of literature: influential special issues of journals, bibliographies, anthologies, and readers. These collaborative publications present unique moments in which the highly interdisciplinary field of feminist science studies articulated itself to a broader audience, and they offer an insightful perspective on its sources and the evolution of thought and core themes in the field.[2] As we will see, a central finding of this brief sketch of feminist science studies is the way in which feminist philosophical critiques and reconstructions of science have been shaped in part by their vital role in the broader feminist project in academia. Feminist philosophy of science, that is, has been formed in the context of two different challenges: building oppositional epistemologies to ground feminist scholarship in the social sciences and humanities, and offering critiques and reconstructions of the (natural and social) sciences. To appreciate the central themes and debates within feminist philosophy of science, it is necessary to understand the nature of the exchange between these projects.

The Autumn 1978 issue of *Signs*, a special issue entitled "Women, Science, and Society," and edited by Catherine Stimpson and Joan Burstyn, represents the first multidisciplinary, multiauthor work exclusively on the subject of science and clearly grounded in the field of academic feminism. At this time, *Signs* was one of only a few full-fledged academic journals in the field of women's studies. This first collection of what today would be recognizable as "feminist science studies" featured scholarship in three areas: critiques of gender bias in science, history of women in science, and social science data and public policy considerations on the status of women in the science professions.

The critiques of science focused on biological research on sex difference: Adrienne Zihlman on the "man the hunter" theory in anthropology, Donna Haraway on models

Footnote 1 continued
projects such as gender studies and science studies. The lumping together of diverse intellectual developments, with widely variable theoretical underpinnings, obscures the particular sources, locations, and areas of influence of feminist work on science. It is also complicit with distortive polemic critiques, exemplified by Paul Gross and Norman Levitt's *Higher Superstition* (1994), which blur post-1960s work in fields such as feminist studies and science studies with poststructuralism and a range of other projects, in order to dismiss it as illegitimate scholarship that is ideologically-driven and anti-science.

[2] My focus on journals, in particular, as a means of reconstructing the core currents in the historical development of the field of feminist science studies is supported by several sources. Maurice McDermott's (1994) study of feminist journals in the history of academic feminism underlines the essential role these journals have played in providing the backbone of the "knowledge dissemination network" for feminist scholarship. In the scholarship on women and science this has been especially true. Tania Zanish-Belcher (1998) looked specifically at the role of journals in feminist scholarship on women and science, finding that this work has been almost exclusively represented in feminist journals. *Hypatia* and *Signs* are the top scorers in citational studies for publications on gender and science. *Isis* scores third, but this literature is principally on the history of women in science, a category of work that, as I will demonstrate, is problematically situated in feminist science studies and feminist philosophy of science in particular. Zanish-Belcher concludes that this field 'has had to create its own forum where it may be heard and published more frequently' and that 'traditional mainstream journals ... have neglected the topic of women and feminism in science' (ibid., p. 212). These conclusions are confirmed by my own keyword searches in 23 journals in feminist studies, history of science, sociology of science, technology studies, and philosophy of science for this study. In addition, they provide support for my view that feminist science studies is best institutionally and intellectually located in academic feminism, and not, for example, in science studies.

of sociality in primatology, a review piece by Ruth Bleier on "Bias in Biological and Human Science," Helen Lambert analyzing scientific theories of sex difference, and Marian Lowe critiquing sociobiological theories of gendered behavior.

Work on women in the history of science featured in the 1978 *Signs* concentrated on American and European women in the nineteenth and twentieth centuries. Reproductions of photographs of "Female Medical Students at the Turn of the Century" and the correspondence that led to the 1897 founding of the "Naples Table Association for Promoting Scientific Research by Women" appear in the issue. Sally Gregory Kohlstedt's contribution, "In from the Periphery: American Women in Science, 1830–1880," begins to sketch the now well-established story of women's increasing exclusion from medicine and science with the rise of professionalism in the nineteenth century and to recover the neglected stories of women scientists from this period. Historian Lois Magner combs through the work of key early feminist thinkers such as Mary Wollstonecraft and Charlotte Perkins Gilman to reconstruct their approach to the "science question" in feminism.

A third set of articles exhibited social science research on the status of women in the science professions. Margaret Rossiter's "Sexual Segregation in the Sciences: Some Data and a Model," articles on "Women in Science" and "Women in Medicine," by Michele Aldrich and Dorothy Rosenthal Mandelbaum respectively, and Anne Briscoe's account of the role of women's caucuses within the various scientific professional associations in increasing the status and visibility of women in the sciences, exemplify this area of research in the 1978 *Signs*.

In the long view of the development of feminist science studies over four decades, the 1978 special issue of *Signs* was remarkably comprehensive in the range of work that it included within the scope of gender and science questions. The three featured areas of scholarship, gender bias in science, the history of women and gender in science, and the status of women in the science professions, largely remain the prominent strains of feminist science studies today. It was also generative of foundational early scholarship in the field. Scholarship in this 1978 special issue previewed the surge of important books published in the 1980s on the subject of women and gender in science. Among the influential texts that find their first venue in the 1978 special issue are Bleier's *Science and Gender: A Critique of Biology and its Theories on Women* (1984), Rossiter's *Women Scientists in America: Struggles and Strategies to 1940* (1982), Lowe and Ruth Hubbard's (Eds.) *Woman's Nature: Rationalizations of Inequality* (1983), Mandelbaum's *Work, Marriage, and Motherhood: The Career Persistence of Female Physicians* (1981), and later, Haraway's *Primate Visions: Gender, Race, and Nature in the World of Modern Science* (1989).

Moreover, the editors of the 1978 *Signs* were remarkably prescient in anticipating the debates that feminist scholarship on science would provoke and in articulating the relevance of critical studies of science to feminist studies. Framing the subject of gender and science and justifying the devotion of a special issue to it, Stimpson and Burstyn's introduction records for us how feminist science studies was, from its beginnings, assigned a special place at the heart of the embattled enterprise of academic feminism. Citing Florence Howe's report on the progress of the establishment of academic feminism in the academy, "Seven Years Later: Women's Studies Programs in 1976" (1977), the editors noted that although feminist scholarship had blossomed in

many other areas, science had been a source of "surliness" and "belligerent scrutiny" (1) of feminist work. In the 1970s, science was not only an institution that appeared hostile to women in its professional ranks and deeply implicated and entrenched in a history of providing ideologically-motivated support to sexist theories of gender difference. It was, more broadly, a generative locus of threats to the legitimacy of feminist work in the academy.

Conceptions of science as a model epistemology for social science and humanities scholarship, the editors pointed out, helped to undergird three common early critiques of feminist scholarship. The first was that scholarship on women is marginal in the sense that it is only about, and therefore only relevant to, women, while good scholarly work, on the model of science, contributes to and speaks for all of humanity. The second was that feminist scholarship is ideologically motivated, and thus cannot meet standards of scholarly work, which was conceived, on the model of science, as defined by neutrality, objectivity, and rational public debate. Third, detractors claimed that while feminists may have a valid critique of gender inequality, there is nothing about the feminist critique that provides a methodology or epistemology to underpin a distinct scholarly program for research or teaching, as the established disciplines, using the model of science, have been able to accomplish. From the inception of academic feminism, those who launched the most powerful critiques of feminist work were not only mobilizing science-based arguments about the biological inevitability of gender differences and roles, but also implicitly or explicitly about the legitimizing epistemology of the academy.

Publications on gender and science proliferated in the 1980s. The early eighties welcomed several texts today regarded as canonical in the field, by scholars such as Merchant (1980), Keller (1985), Harding and Kintikka (1983), Harding (1986), Fausto-Sterling (1985) and Bleier (1984, 1986), and by the end of the decade, Longino (1990), Haraway (1989, 1991) and Schiebinger (1989). My discussion here focuses on four key collaborative texts. First, a back-to-back set of special issues of the feminist philosophy journal *Hypatia* on "Feminism and Science" in Fall 1987 and Spring 1988, edited by Nancy Tuana, which later became the first well-circulated reader on the subject, *Feminism and Science* (Ed. Tuana 1989). Second, the 1989 special issue of *Women's Studies International Forum*, "Feminism and Science: In Memory of Ruth Bleier," edited by Sue Rosser. Third, an exhaustive guide to the field, "Philosophical Feminism: A Bibliographic Guide to Critiques of Science" (1990), prepared with government funding for the Canadian publication *Resources for Feminist Research* over the period 1987–1990 by Alison Wylie, Kathleen Okruhlik, Sandra Morton and Leslie Thielen-Wilson. Finally, a 1990 article by Helen Longino and Evelynn Hammonds, "Conflicts and Tensions in the Feminist Study of Gender and Science," which reflects upon the development of the field of feminist science studies in the 1980s.

In the 1970s, feminist science studies was principally the domain of feminist scientists and historians of women in science. In the 1980s it became a stronghold of feminist philosophers. *Hypatia*, today the leading journal of feminist philosophy, grew out of the American branch of the Society for Women in Philosophy (SWIP) during the mid-1980s. Most of its contributors are analytically-trained American philosophers. *Hypatia* was incubated in the pages of the *WSIF* from 1983 to 1985, and the *Hypatia* and *WSIF* special issues I discuss here mark the arrival of a clear philosophical turn

in feminist science studies scholarship in the 1980s. Both special issues divide their articles between theoretical discussions of feminist approaches in science and applied case studies of gender bias in science. Philosophers Sandra Harding and Longino, and the philosophically-inclined Rosser and Keller, are featured in these special issues. The bibliography on feminism and science—assembled by Canadian philosophers, published in annotated form in the 1989 *WSIF* special issue, and filling 35 dense pages in the June 1990 *Resources for Feminist Research*—documents the dramatic rise of feminist science studies scholarship in the 1980s. Its title "Philosophical Feminism: A Bibliographic Guide to Critiques of Science," crystallizes the close alignment between the projects of feminist philosophy and feminist science studies during this period.

Rosser's opening essay in the 1987 *Hypatia* special issue, "Feminist Scholarship in the Sciences: Where Are We Now and When Can We Expect A Theoretical Breakthrough?" provides insight into the project for a "feminist epistemology," "feminist theory of science," or "feminist philosophy of science" that riveted feminist science studies scholars of the 1980s. As Rosser wrote, "the recent increase in amounts and variety of feminist scientific scholarship may be building the foundations for more theoretical work towards a feminist transformation of science" (p. 5). This project was intimately linked to the broader feminist vision of rethinking the disciplines at a time when feminist work in a range of disciplines was gaining more mainstream status. Continued Rosser, "Feminists from a variety of disciplines must examine the effect that feminism has had on their discipline….What we need are more feminist scientists, feminist historians, feminist philosophers and feminists in every discipline" (p. 13). This theoretical turn, with an emphasis on transforming the disciplines, laid the groundwork for the development of the field of "feminist epistemology" in the late 1980s. Building on insights from feminist critiques of science and the alternative approaches to scientific research that were implicit in these critiques, feminist epistemology took up the positive project, precisely as described by Rosser, to construct new models for knowledge outside of conventional ones that had served, it was believed, to exclude the voices of women and minorities.

Feminist critiques of science provided academic feminism with theoretical tools for moving from critique to positive methodology. Feminist science studies scholars worked to challenge the prevailing ideal of a neutral, value-free science and build models for a more democratic, feminist, or emancipatory science. With sophisticated critical analyses of core methodological concepts in the sciences, feminist science studies scholars, and philosophers in particular, could explain how a critique of concepts like "value neutrality" did not also entail a lack of commitment to traditional scientific values like "empirical adequacy," "reality" or "objectivity." This body of work helped feminists across the disciplines to negotiate their way toward "legitimate" scholarship. It enabled feminist scholars to work with the conventional criteria for academic scholarship while building new methodologies, paving the way for important inroads within in the traditional disciplines, particularly in the humanities and the social sciences.

Wylie et al.'s 1990 bibliography provides a valuable snapshot documenting the extensive impact of this project for a "feminist epistemology" across the academy during the 1980s. Organized by discipline and field, including anthropology, sociology, psychology, history, biology, and "women in technology," the bibliography

surveyed feminist literature from the 1980s that questioned the conventional epistemological values of each area of research. The bibliography citationally demonstrates how literature from feminist philosophical critiques of traditional conceptions of science, sociology of science, and the history of science constituted core sources of these feminist interrogations of disciplinary methods.

As the editors of the 1978 *Signs* special issue anticipated, feminist studies of science, which spoke to fundamental epistemological issues in feminist debates, would become central to the establishment of academic feminism. Today, Harding's concept of "strong objectivity" (1985) and Haraway's concept of "situated knowledges" (1987) are cited across diverse areas of the humanities and social studies as grounds for the claims to knowledge of subordinated groups and as starting points for epistemological critique. And within analytic philosophy of science, Longino's *Science as Social Knowledge* (1990) brought insights from feminist epistemology and social studies of science into mainstream debates in scientific epistemology and methodology and helped to ground the subfields of social epistemology and feminist philosophy of science.

What became "feminist science studies" during the 1980s was an increasingly theoretical or philosophical mode of science criticism tied to an ambitious and even utopian project of refiguring the very terms we employ to speak of core epistemological concepts. The theoretical turn in feminist science studies corresponds to developments in many fields of academic feminism during the 1980s. One factor in this shift was the increasing professionalism and subspecialization of academic feminism—and its related growing distance from grassroots feminism—initiating a movement from ideology to "theory." Another factor was increased recognition within the feminist community in the 1980s that work on "women" as a category makes intersectional oppressions such as those based on race, class, and sexuality invisible and falsely essentializes women's experiences, leaving projects like "history of women scientists" or "the status of professional women in science" appearing unsophisticated and elitist.

This theoretical turn led, in the 1980s, to a parting of ways between scholarship on "women in science" and "feminist critiques of science," in which the latter, the province of philosophers and the theoretically-inclined, became the gatekeeper for the field. Longino and Hammonds' "Conflicts and Tensions in the Feminist Study of Gender and Science" (1990) documents the growing schism between "epistemological critiques" and "the matter of women in science" during the 1980s. While the editors of the 1978 *Signs* issue saw the multifaceted projects of the feminist study of science as easily "hanging together" around the shared vision of a science that would be open not only to women and minorities but also to subordinated ways of knowing, they seem not at all to have anticipated that women scientists might not share their critiques and hopes, or even identify as feminists. As Hammonds' contribution records, feminist science critics quickly learned that most women scientists believe that "*science just works*" and that "science is *defined* as the product of scientific method—a method that self-corrects for all human biases" (p. 180, original emphasis). Without a "clearly articulated alternative to conventional practices" women scientists found feminist critics "incomprehensible" (p. 180). The result, by the early 1990s, was a field sharply divided between critical approaches to science and projects to help women achieve gains in their careers as scientists.

Despite these fissures, by the late nineties and beyond, feminist science studies was big, confident, robust, and well-established. Today, the literature is vast, and leading feminist science studies scholars such as Fausto-Sterling, Keller, and Haraway are well-known public intellectuals whose writings have become canonical in social, historical, and philosophical studies of science. Four special issues anchor my account of the mid-1990s and early 2000s: the 1995 *Synthese* issue on "Feminism and Science," edited by Lynn Hankinson Nelson; the 1997 *Osiris* issue on "Women, Gender, and Science: New Directions," edited by Sally Gregory Kohlstedt and Longino; the 2003 *Signs* issue, "Gender and Science: New Issues"; and the 2004 *Hypatia* issue, "Feminist Science Studies," edited by Nelson and Wylie. The picture is filled out by several readers and anthologies published over the last fifteen years: *Feminism and Science* (Ed. Keller and Longino 1996); *Feminism, Science, and the Philosophy of Science* (Ed. Nelson and Nelson 1996); *Feminist Science Studies: A New Generation* (Ed. Mayberry et al. 2001); and, *The Gender and Science Reader* (Ed. Lederman and Bartsch 2001).

Nelson prefaced the 1995 *Synthese* special issue, "Feminism and Science," by citing the 1995 New York Academy of Sciences conference, "The Flight from Science and Reason." The message of the conference, trumpeted by the *New York Times* and the global press, was that faith healers and parapsychologists, alongside science studies and feminist science scholars, were posing a threat to the advancement of science and to the public ideal of reason. According to the conference organizers, feminist science scholars were "relativists" who "deny the possibility of scientific knowledge" (p. 329). The *Synthese* volume stepped into this climate, with six diverse and searching philosophical essays by Harding, Elisabeth Lloyd, Tuana, Longino, Nelson, and Elizabeth Potter on objectivity, evidence, theoretical virtues, Quinean naturalization of philosophy of science, and the distinctiveness of feminist approaches in philosophy of science. This work represented the achievement of a decade of feminist philosophical investigations in science. While exhibiting rich debates among the contributors, the volume also communicated a strong uniting theme that feminist philosophy of science was neither relativist nor anti-empirical, but instead invested in advancing good science and developing stronger conceptions of both objectivity and empirical adequacy.

The 1997 special issue of *Osiris*, "Women, Gender, and Science: New Directions," was the product of a conference held at the University of Minnesota in 1995, organized by Kohlstedt and Longino, to "collectively assess where we are in the mid 1990s" (p. 3). The conference foregrounded three themes of 1990s feminist science studies: to consider the implications of the problematization of key terms and concepts in feminist scholarship, such as "feminism," "gender," and "woman," for feminist research on science; to revisit the problem of the lack of progress of women in the sciences and its relationship to the agenda of feminist science studies; finally, to reinvigorate the field's interdisciplinarity, by building "new relationships among feminists engaged in science studies" (p. 13).

The tension between the philosophical and "women in science" strains of scholarship seen in the 1980s continued to occupy the field during the 1990s. The 2003 *Signs* special issue on "Feminist Science Studies" features an article cluster edited by Schiebinger on "women in science," with updated reflections by Hammonds on the relationship between feminist science studies and the goal of advancing woman in

the science professions. Revisiting her 1990 discussion of this question, Hammonds found that these "tensions" have developed into "schisms" (p. 926) during the 1990s. Describing her experiences speaking on panels at conferences on women in science, Hammonds wrote:

> The feminist science scholars want to talk about what gender means, how gender functions, what race difference means, and how race functions in relation to science. We want to talk about social structures, we want to talk about the context in which scientific communities work, we want to talk about power relations. We want to think about how science works within complex societies. By and large, women scientists want to talk about role models. Therefore what occurs is for me a predictable performance by all involved. (p. 941)

Hammonds' experience, heightened and hardened since the publication of "Conflicts and Tensions" 13 years previously, suggests that the relationship between gender and science and women in science questions not only continued to challenge feminist science studies, but expanded and became further entrenched in the coming decade.

The term "feminist science studies" first appears in the 1990s, marking cross-pollination between the then-emerging field of "science studies" and feminist scholarship on science during this period. In the 1990s, feminist science studies and the burgeoning field of "science studies" encountered each other, resulting in new innovations and a flowering of interdisciplinarity—and mutual embroilment in the 1990s "science wars." In part as a result, feminist science studies continued to find itself at the center of charged debates over core epistemological concepts such as "objectivity" that remained closely tied to the plight of academic feminism during the 1990s. In the introduction to the *Hypatia* special issue on "Feminist Science Studies" (2004), Nelson and Wylie looked back on the 1987–1988 *Hypatia* special issues on "Feminism and Science" that are discussed above. They noted that feminist science studies now "presupposes a number of hard-won insights that were just beginning to emerge in the mid-1980s" and has "matured and diversified in many respects" (p. vii). At the same time, the editors found themselves addressing old polarities and arguments present in the 1978 *Signs* issue and the 1987–1988 *Hypatia* issues. The continuing perception of feminist science studies as anti-science is a matter to which I will return below.

In this brief review of three decades of feminist science studies and feminist philosophy of science, I have argued that since the 1970s, feminist science studies has occupied a special place in the negotiation of academic feminism's claim to scholarly legitimacy. "Is feminist work legitimate scholarship?" was the question on which academic feminism cut its teeth. A particular model of science, emphasizing the "value neutrality" of the observer, had been the predominant model for the regulation and legitimation of scholarship in the American academy since the nineteenth century (Novick 1988). The philosopher John Searle concisely captured this worldview when he characterized feminism as a "cause to be advanced" rather than a "domain to be studied" (1993, p. 73). Feminist thought has challenged this epistemological model, first in the oppositional forms of knowing that flourished in the free universities and consciousness-raising groups of the 1960s, then as it became established in interdisciplinary locations in the academy in the 1970s, and finally in the 1980s and 1990s as it became mainstream in many disciplines (DuPlessis and Snitow 1998; Boxer 1998).

Feminists have forged scholarship that explicitly reflects upon the ethics and conditions of academic knowledge production, is grounded in the experiences and knowledge of subordinated peoples, and advances research and values associated with emancipatory politics.

Feminist science studies' institutional location, in terms of the training of its scholars, the journals and readers in the field, and the theoretical backdrop of its work, has been academic feminism. Because feminist philosophy of science has played a key role in articulating the most fundamental critiques of authoritative knowledge in feminist studies, it has been a flashpoint for controversies over academic feminism. Because it engages with the very epistemological questions at the heart of debates over legitimate scholarly methodology, feminist philosophy of science has occupied a unique position among other feminist studies fields—as well as other science studies fields—in grounding the new models of knowledge upon which academic feminism proceeded.

As we will see in the discussion that follows, feminist science scholarship is supremely interdisciplinary. As much as its interdisciplinary location and marginalization has been a challenge for feminist science scholarship, including feminist philosophy of science, it has also been a strength. One must include the work of scientists and other non-philosophers in order to properly describe the field of feminist philosophy of science and its contributions. With toeholds in multiple disciplines and professions, feminist scholars of science have been able to produce creative and penetrating critiques of science and to forge novel approaches within their home disciplines.

2 Contributions

With this backdrop of its history and context in place, we may now sketch the central questions, debates, and contributions unique to feminist philosophy of science. Feminist philosophy of science, primarily through the use of case studies, has advanced research in classic areas of philosophy of science and opened up philosophy of science to new and fruitful investigations.

2.1 Case studies of gender bias in science

The case study has been the traditional format for philosophical work on gender bias in science. The author presents a methodological critique of gender bias in a particular scientific research program, theory, or explanatory framework. He or she shows how gendered practices or assumptions in a scientific field prevented researchers from accurately interpreting data, caused inferential leaps, blocked the consideration of alternative hypotheses, overdetermined theory choice, or biased descriptive language.

Feminist investigations of gender bias in biology are a good example of this case study methodology in practice. Feminist scientists, philosophers, historians, and science studies scholars began examining biological theories of sex and gender in the 1970s, and there is a now substantial and well-regarded case study literature on gender bias in particular areas of the sciences. Some prominent examples of case study work on gender bias in biology include Joan Rough-

garden's (2004, 2009) analysis of gender conceptions in sexual selection theory, Lloyd's (2005) recent study on bias in evolutionary models of the female orgasm, Tanner and Zihlman's (1976) findings of sexism in man-the-hunter theories of the evolution of human culture, language, and cognition, Keller's (1992) critique of the assumption of reproductive autonomy in population genetics, and Longino and Ruth Doell's (1983) analysis of ideology in hormonal theories of gender differences in behavior. Similar case studies have been documented in many areas of the sciences, including medicine, archaeology, engineering, physics, and the social sciences.

In *The Case of the Female Orgasm: Bias in the Science of Evolution* (2005), Lloyd shows how evolutionary biologists' androcentric assumption that the female orgasm must serve a reproductive function similar to the male orgasm led researchers to ignore clear evidence contradicting this model and to neglect more empirically adequate explanations of the evolution of female sexuality. Her hard-hitting critique targets core assumptions of classical evolutionary models of human female sexuality, which typically conceive of female sexual behavior only in terms of its role in reproduction. Provoking extensive debate among human evolutionary biologists, her analysis has led to new developments in this field, including empirical studies to test her alternative model of the evolution of the human female orgasm (Wallen and Lloyd 2008a,b).

Roughgarden's *Evolution's Rainbow* (2004) and *The Genial Gene* (2009) present a penetrating critique of predominant assumptions in sexual selectionist evolutionary models of mating behavior and offer a potentially revolutionary alternative theory, which she calls "social selection." According to the theory of sexual selection, first proposed by Charles Darwin and developed and amended extensively during the twentieth century, females choose mates among males who compete with one another for female attention. This model of mating behavior is used to explain everything from why males in some species develop exuberant male ornamentation (often said to be a sign to the female of a male's superior genetic endowment), to the greater role of the female in rearing offspring, to the supposed female preference for monogamy and male instinct for promiscuity. Roughgarden shows how central supporting assumptions of sexual selection are invisible to its proponents and often undefended. Extracting these central premises, making them explicit, and examining the evidence, Roughgarden finds that many of them are not only empirically undersupported, but rife with ideological assumptions. Even Darwin's famous example of the peacock tail, a touchstone for analogical reasoning in sexual selection theory, is revealed by Roughgarden to be a questionable case of sexual selection. The alternative offered by Roughgarden, social selection, repositions animal mating behavior as reproductive social behavior that serves many functions beyond mating, including social bonding and the raising of offspring. This alternative model presents empirically testable hypotheses and is now inspiring robust debates in the field and new theoretical research in evolutionary ecology (Roughgarden et al. 2006; Dall et al. 2006; Clutton-Brock 2009; Carranza 2009; Roughgarden and Akcay 2009; see also Millstein forthcoming).

Case study analyses of gender bias in science have been highly influential within both philosophy and the sciences. As exemplified by Lloyd's and Roughgarden's critiques of gender assumptions in evolutionary biology, feminist work on gender bias in biology has led to changes in scientific practice and has aided efforts by femi-

nist and gender-critical scientists to challenge sexist, androcentric, and heterosexist research models in biology (for additional examples, see Haraway 1989; Schiebinger 1999; Creager et al. 2001; Gowaty 2003; Schiebinger 2008; Richardson 2008). By underscoring how science can come to reflect the ideology of its practitioners in ways that are not apparent to them, work on gender bias in scientific knowledge has also supported efforts to bring about diversity and inclusion in the science professions (see Fehr 2010). Finally, detailed case study work on gender bias in science has formed the bedrock material and motivation for reconstructive projects in feminist epistemology and philosophy of science over the past decade.

Currently, there is a mismatch between the significance of case study analysis of science for the development of the philosophy and practice of science on the one hand, and the prestige that the discipline of philosophy awards such work on the other. Journal referees, funding sources, graduate training, and tenure demands often brand case study work, dismissively, as "applied" philosophy of science, and yet it represents some of the most socially relevant work in philosophy of science. As a scholarly community, philosophers of science must strive to make case study work on the social and political dimensions of scientific knowledge more mainstream, rewarded, and prestigious.

2.2 Novel questions in philosophy of science

The philosophical relevance of the "gender and science" question goes considerably beyond the identification and diagnosis of gender bias in particular areas of the sciences. As Keller (1992) argues, reflection on gender and science presents *kinds of questions* that may be used as tools for probing historical, philosophical, and social dimensions of science. Studies of gender in scientific knowledge raise original, integrative, and challenging questions about science, questions that are not applicable simply to gender, but prove useful for analyzing science in general.

Feminist scholarship has demonstrated that sex and gender constitute primary categories in human social life and that gender attributions are deeply embedded in human knowledge, language, and symbolic culture. Gender norms are, as Keller writes, "silent organizers of the mental and discursive maps of the social and natural worlds we simultaneously inhabit and construct" (1992, p. 17). "Masculinity" and "femininity" not only categorize men and women, but schematize abstract concepts such as reason and emotion and mind and body. In this way, feminist approaches to science, Keller continues, "expose to radical critique a worldview that deploys categories of gender to rend the fabric of human life and thought along a multiplicity of mutually sanctioning, mutually supportive, and mutually defining binary oppositions" (p. 18). This has consequences for the organization and valuation of forms of human knowledge, the perceived authority of differently embodied knowers, the practice of science, and the structure of scientific explanations of nature (see Traweek 1988; Daston 1991; Lloyd 1993; Schiebinger 1993).

Science has helped to construct and enforce dominant human conceptions of sex differences and gender norms. For example, biomedical claims are frequently used as a justification for maintaining women's traditional domestic and child-

bearing roles. In the nineteenth and early twentieth centuries, scientists and others deployed a biological and medical conception of womanhood as defined by reproductive organs and imperatives in arguments against the education of women, women's suffrage, and the competency of women in the professions (Smith-Rosenberg and Rosenberg 1973; Poovey 1986; Jordanova 1989; Russett 1989; Lunbeck 1994). Gender also valences scientific language, inflects science's status as an authoritative social institution, and encodes the practices and norms of scientific communities. From Bacon's seventeenth-century call to "raise a masculine science" (Schiebinger 1989) and the gentlemanly mannerisms that governed British scientific societies' conceptions of "objective knowledge" (Daston 1991), to the no-girls-allowed clubhouse social worlds and the modes of dress and décor found in contemporary computer science (Margolis and Fisher 2002), gender has been central to the organization of scientific cultures. The complex of "gender and science," then, presents a rich case of the mutual interaction and dependence of human culture and scientific accounts of nature, forcing consideration of the relationships between scientific knowledge, nature, culture, power, desire, and ideology in ways rivaled by few other problematics.

First, philosophical analysis of gender and science leads to the reexamination and reframing of central questions in philosophy of science. Gender and science questions have served as a starting point for thinkers to hasten along, justify, and deepen post-Kuhnian and post-Quinean reconstructive philosophical projects. Feminists such as Harding, Haraway, Longino, Wylie, and many others have labored to build a philosophical account of science that captures a naturalized, sociological and ethnographic understanding of science as a social practice with institutional, rhetorical, ideological, and social-structural dimensions. Over the past 25 years, feminist philosophers of science carried the leading edge of this work, recasting traditional philosophical questions about the nature of concepts such as objectivity, value-neutrality, theory-ladenness, underdetermination, and pluralism, and crafting newer concepts for understanding science such as contextualism, epistemic communities, and background assumptions.

Second, science and gender raises new, nontraditional questions for philosophy of science. Feminist philosophers of science have forged a hybrid practice, moving between naturalized descriptions of science and constructive reformulations of scientific norms. This approach integrates standard epistemological investigations with questions about the social responsibilities of scientists and the social norms and practices of the scientific community. Longino (1996), for instance, crafts a vision of "democratic science" characterized by "cognitive democracy." To achieve this, she argues, it is insufficient to merely describe science more accurately in its full social context; rather, "the structures of cognitive authority themselves must change" (p. 278). This requires "an adequate normative theory" (p. 265) of the regulative norms of scientific knowledge production. Barad's (1998, 2007) agential realism, Harding's (1993) "strong objectivity, Keller's (1985) "dynamic objectivity," and Longino's (1990, 2002a) "norms of transformative criticism" are all examples of normative accounts of how scientific ways of knowing might be brought more in line with human values. These approaches refigure questions in philosophy of science and succeed in registering the distinctive and much-needed voice of the philosophical humanities in discussions around the sciences.

These approaches and insights are not wholly unique to feminist engagement with science, nor to the problematic of gender and science. Gender, however, stands as a bright window through which philosophers of science can learn more about their object of study and expand their questions and frameworks. Sustained engagement with questions at the intersection of gender and science can only deepen philosophical accounts of the interface of science and culture and thereby expand the ways in which philosophy of science might become more socially relevant.

2.3 Modeling interdisciplinary approaches

A signature of the highly influential philosophical scholarship on gender and science cited here is its interdisciplinarity. Philosophical studies of gender and science draw strength, relevance, and sophistication from critical and responsible engagement with the relevant literature of gender studies, as well as that of other fields such as science and technology studies. The conventional terms of analytic philosophy of science are of limited use for analyzing questions about science in a way that instantiates it fully in its ideological, social, and historical dimensions. Historically, feminist philosophical analysis of science has mandated intra- and interdisciplinary engagements between philosophy of science and ethical, moral, social, and political philosophy, continental philosophy, rhetoric, and cultural theory.

Interdisciplinary institutional contexts, training, and engagement are a strength of feminist philosophy of science. Scholars in this field often must be experts not only in their areas of science and philosophy, but also in the social space in which they are seeking to intervene. Modeling these interdisciplinary approaches constitutes one of the contributions of the field of feminist philosophy of science. Within the current structure of the academy, interdisciplinary work is disadvantaged, in part because of the perception that decreased productivity must result from acquiring this broad knowledge base. Shifting the reward and institutional structure of philosophy to support and prize philosophers' strong ties to interdisciplinary fields such as gender studies, then, is an important means of nurturing socially relevant and politically engaged philosophy of science.

3 Challenges

Among the central challenges that feminist philosophy of science faces are the continuing marginalization of feminist philosophy within philosophy, the persistent difficulty of translating feminist ideas in ways that do not invite dismissal and hostile caricature, and moving beyond questions of "bias" in philosophical analysis of gender in science.

3.1 Continuing marginalization

Feminist philosophy continues to be marginalized within the academic profession of philosophy in ways that limit the productivity, visibility, and impact of feminist philosophers of science. Marginalization of feminist philosophy is perpetrated in explicit and traditional ways, including near-exclusion from elite publication venues, lack of tenure-track faculty lines in the field, and failure to integrate feminist philoso-

phy and female philosophers into the philosophical canon and curriculum. It also takes place in subtle everyday ways, through discursive and disciplinary constructions that exclude, other, and delegitimize gender as a properly philosophical topic and feminist thought as a properly philosophical occupation.

The marginalization of feminist thought is, in part, continuous with the marginalized status of women and minorities in the discipline of philosophy. Women and minorities are sorely underrepresented in philosophy as compared with peer disciplines. Sally Haslanger's (2008) recent analysis of why women and minorities continue to choose not to pursue philosophy, or often leave the professional track when they do, is revealing. She finds that hostile professional culture and outright discrimination continue to marginalize and exclude women. Women in philosophy report sexual harassment, "chilly climate" (p. 2) issues such as social isolation and aggressive and judgmental professional ethos, and constant inappropriate judgments of personal life choices such as marital status or plans for children, judgments not made of men who make the same choices. Writes Haslanger, "Women, I believe, want a good working environment with mutual respect. And philosophy, mostly, doesn't offer that" (p. 3).

Quality and number of peer-reviewed publications is the principal criterion for advancement in academic philosophy. Haslanger presents data suggesting sex discrimination in peer review evaluation for publication. Surveying the content of seven leading philosophy journals between 2002 and 2007, Haslanger found that 12.36% of authors were women and that feminist content represented only 2.36% of articles.[3] Women make up 18.7% of tenured and tenure track positions in the top 20 American philosophy departments, and women in philosophy, far more frequently than men, include feminist philosophy among their teaching and research competencies. Observes Haslanger, "The virtual absence of feminist philosophy in the journals considered stands in stark contrast to the acceptance of feminist work in other humanities and social sciences. Philosophy is, and is generally perceived to be, reactionary in this respect" (p. 7). Combined with the opaque, non-double-anonymous peer review practices of most leading journals documented by Haslanger, these findings about the representation of women authors and feminist work in the leading journals of the profession point to severe professional barriers for women and feminists in philosophy.[4]

An example of how these practices of disciplinary marginalization affect the professional status of feminist philosophers of science and the reception of their work within

[3] Although the data are limited, in order to rule out that women, proportionally, are submitting fewer papers to these journals, Haslanger compared the rates of female authorship and feminist content, respectively, in comparable field-specific journals. Whereas representation of women in the top philosophy of mind and philosophy of language journals was between 6 and 12%, it was 26.5% in *Mind and Language* and 24.4% in *Linguistics and Philosophy*. Of course, if women are submitting fewer papers to the top journals, that is also alarming, and may point to other structural and cultural problems for women in philosophy.

[4] Haslanger did not look at the peer review policies of top journals in the field of philosophy of science in her 2008 paper. Both *Philosophy of Science* and the *British Journal of Philosophy of Science* promise "blind review" on their websites. In interviews with editorial board members of leading journals in philosophy, Haslanger shows, however, that "there is a wide variation among philosophy journals in how 'blind' the review process is" (p. 7), even when journals promise it.

philosophy of science is the 2002 exchange between Philip Kitcher and Longino in the pages of *Philosophy of Science*. Having recently authored new books on science, values, and society, in 2002 Kitcher and Longino were each invited to review the other's book and then respond to one another. Kitcher's review of Longino's book, *The Fate of Knowledge* (2002), is a jaw-dropping example of condescension, derogation, and belittling treatment of a female, and feminist, colleague. In a swaggeringly abusive tone that may predominate in the back rooms but is rarely encountered in published philosophical exchange, Kitcher delivered a screed of scattered philosophical arguments mixed with a rhetorically flamboyant portrayal of Longino as out of her league, emotionally awry, and working in the realm of ideology rather than philosophy.

Kitcher described Longino in gendered code, repeatedly calling her efforts "obsessive" (pp. 550, 558, 559, e.g.), portraying her critiques of other philosophical positions as "her frequent castigation of other people" (p. 553), and branding her approach as juvenile, presumptive, and officious: "Special Prosecutor Longino is on the case," he mocked (p. 549). Kitcher also implied that Longino was purely ideological, and thus not a worthy philosophical interlocutor. He compared Longino's positions to the "isms" of British politics and dubbed Longino's perspective "Interactionist Socialism." Twice, Kitcher found wholly out-of-context ways to mention Longino's feminist affiliations in his review. In the middle of a discussion of pluralism, he inserted this odd analogy: "But inconsistency is evaded here precisely because the claims are partial: the point is as boring as the lack of difficulty in identifying Helen Longino as a member of both Minnesota's Philosophy Department and of its Center for Advanced Feminist Studies" (p. 555). The irrelevant aside seems clearly intended to communicate an insider's snicker to a particular kind of imagined reader, a fellow guardian of the values and standards of the discipline.

Kitcher's onslaught provoked a remarkably restrained response from Longino (2002b), but one that slyly flags the disciplining moves and sexist prerogatives at work in his commentary. "The Third Way? The specter of communism?" (p. 573), Longino began, "At risk of re-exile to the margins, I must decline the apple and reclaim my own position in the garden" (p. 574). Both Kitcher and Longino have been my teachers, and my intention here is not to adjudicate their debate, nor to personally attack Kitcher. My focus is on the gender dimensions of this particular exchange, which I believe are worthy of airing and analysis in the context of a discussion about the challenges faced by feminist philosophers of science. Reading this exchange, I believe, would give any female philosopher a chill of recognition, and any aspiring feminist philosopher serious pause about her prospective discipline's commitment to rigorous reasoned dialogue.

3.2 Dilemmas of translation

Feminist philosophical critiques of gender bias in science are frequently simplified, distorted, or truncated when translated by scientists, non-feminist philosophers, and general readers. As a result, despite the significant body of reference literature and conceptual frameworks developed by feminist philosophers of science, and the many examples of the influence of this work, translating those frameworks into socially relevant work remains difficult.

A well-documented translation problem is the persistent reception of feminist critiques of science as "anti-science." Gross and Levitt's *Higher Superstition* (1994), a harsh polemic on the "academic left" and its ingrained "hostility to science" (p. 2), is among the most notorious examples of this line of attack. A chapter devoted to feminist science studies scoffs at the "self-styled empiricism" (p. 109) of feminist critiques of science and claims to "expose" (p. 109) feminist science studies as wildly constructivist and anti-science. With derisive chapter subtitles such as "Feminist Algebra," "Haploid Hermeneutics," and "Cherishing the Ovum," the authors attempt to characterize gender and science scholarship as unadulterated ideology and impute that feminist scholars of science are anti-science and gynocentric.

The view that feminist critiques of science are "anti-science," common in the reception of feminist scholarship on science beyond the field, takes three principal forms:

1. Feminist science scholars aim to diminish and limit the influence of science (because they believe it to be harmful to women);
2. Feminist science scholars deny scientific findings (such as the existence of biological differences between the sexes);
3. Feminist science scholars reject scientific values, such as objectivity, empirical verification, and logical reasoning (in favor of feminist ideology).

All are stubborn and harmful caricatures of feminist positions that are regularly and explicitly denied by feminist science studies scholars.

Consider the founding moment in feminist studies of science discussed in Sect. 2 above, the 1978 special issue of *Signs*, in which the editors framed central tenets of feminist approaches to science and addressed precisely these attacks and mischaracterizations. These early feminist science studies scholars insisted on the "relevance of science and technology to our lives" (p. 3), refusing those who would argue that science is or ought to be fundamentally peripheral to women's experiences and the emancipatory project of women's liberation. They stressed the complex and contradictory place that science may play in the liberation of women and suggested that even as scientific knowledge, institutions, and technologies may participate in the oppression of women, they may also represent an important tool for improving women's lives. They anticipated the misconception that feminism, because it advances a theory of "social construction" to explain gender difference, embraces an epistemologically inadequate "relativist" or "anti-realist" approach to the study of science. Such a view, they noted, is based on a superficial understanding of the thesis of "social construction." Feminist theories of gender difference do not deny the "reality" of biological or physical difference, and realist and constructivist theses about science need not be inconsistent. As the editors wrote, it is an "obvious truth that women and men are physically different," but "social, cultural, and economic conditions have structured those differences and determined their significance" (p. 1). Feminist scholars working on science, the editors maintained, are interested in encouraging women to enter the scientific professions and innovating institutional changes that support women in science. Furthermore, they noted, a great number of scholars of gender and science are themselves trained scientists. These scientists do not conceive of themselves as attacking, or even offering a general critique of, science, but a local critique of gender bias in a particular area of the sciences.

They conceive of their work as contributing to improving scientific work on women and the nature of gender difference by exposing areas in which scientists have been blind to the workings of gender bias.[5]

A quarter-century later in 2004, the editors of the *Hypatia* special issue on gender and science, also discussed above, are still fighting these battles against misconceptions about the philosophical stance of feminist scholars of science. They are compelled to offer an extended response to those who find "the very idea of a feminist analysis of science" (p. ix) to be a contradiction in terms. They note that the "starkly drawn epistemic options" (p. viii) to which critics wish to hold feminists fail to engage the sophisticated reworkings of these options that feminist science scholars have advanced. They point out that feminist science studies from its inception has been concerned to hold a "middle ground" (pp. viii–ix) that is denied by its critics. Echoing their 1970s counterparts, the editors reiterate that feminist science studies is realist about gender and science: Its critique of science has no commitment to the idea that "the world is…infinitely malleable" or to the "indefinite proliferation of difference" (p. viii). They repeat that feminist science studies is pro-science: Science critique, the editors emphasize, is accompanied by "ambitious constructive projects" (p. ix) to build a better science.

As Lloyd (1996) argues in her essay "Science and Anti-Science," dismissive and misconceived glosses of feminist approaches to science of the kind enumerated above are used to portray feminists as extreme, anti-enlightenment, and unqualified to engage in debates about science. The resilience of these inaccurate perceptions of feminist approaches to science continues to pose a problem for the reach and influence of feminist work on science.

3.3 Moving beyond bias

Finally, feminist philosophy of science is often misconceived, even among its allies, as principally concerned with the issue of gender bias in science. An outsized emphasis on the question of bias glosses over central insights of feminist work on science, represents shaky philosophy of science, and restricts the field's domain, often to the exclusion of plural or more deeply critical approaches to questions at the intersection of gender and science.

These claims may seem surprising given my emphasis above on case studies of gender bias in science as one of the major contributions of feminist philosophy of science. There is no doubt that feminist philosophical analysis of gender bias in science is both important and influential. My concern here is with the highly restricted manner in which the implications of studies of gender bias in science are received within mainstream philosophy of science. Philosophers of science have traditionally sought to be pro-science allies of scientists and have customarily adopted the conception of good science as value-neutral science that many scientists accept. Philosophers of science take epistemic and methodological issues in science to be their domain, and, in this light, bias is an alarming and salient issue of clear philosophical import. This is one reason why, within philosophy of science as a whole, the most central

[5] As demonstrated in Sect. 2, feminist critiques have indeed succeeded in actualizing these improvements in many cases.

and widely-accepted philosophical question related to gender in science is the issue of gender bias in science. Yet this picture of valid feminist philosophical questions about science carries with it a narrow view of the terrain and import of feminist work. Moreover, privileging the problem of bias relies on an idealized, progressive picture of science—in which unbiased, value-neutral science is the ideal. The view of the acceptable, legitimate, or central project of feminist philosophers of science as the surgical correction of gender bias, making the science better by removing ideological assumptions, overlooks central insights of feminist philosophy of science.

Most feminist philosophers of science instead work with some version of an account of science as a value-rich social practice. Longino's (1990, 2002a) account of values in scientific practice is representative. She argues that values are knowledge-productive and constitutive of the cognitive work of science—there is no "value-free" science. It is when gender assumptions are invisible and remain outside of public processes of critical scrutiny (such as publication and peer review) that they may introduce undesirable bias into science. One upshot of this view of values in science is that bias is not necessarily bad. Since science is a social practice, social contextual values and the biases they carry will play an ineliminable role in scientific language, practices, and processes. Furthermore, by driving forward a particular way of thinking, structuring concepts, limiting alternatives, and pressing for consensus, bias can be productive to science and even desirable. Finally, if bias is not something held by individual people who create and test scientific theories, but by communities of scientists and the social context, the diagnosis of bias is not nearly sufficient to correct it where necessary. Rather, this model suggests that we ought to focus on understanding scientific practices in their full social dimensions, and conceiving and developing normative discursive and critical methods and approaches for the sciences (Longino 1992).

To see the importance of moving "beyond bias" in analysis of gender and science, consider three differently-valenced examples from my research on gender in the history of sex chromosome studies.

1. *The assumption that the X is male-determining*: Upon the discovery in 1902 that there are two kinds of sperm, one of which appeared to carry an "extra" X chromosome, cytologists assumed without examining female material that this must be the male-determining gamete (McClung 1902). This was consilient with the going theory, now regarded as a relic of androcentrism in biology, that the male element would necessarily carry the hereditary material and/or activate development. Three years later, detailed empirical studies demonstrated that instead it is the female-determining sperm that carries the X chromosome, reversing the initial hypothesis (Stevens 1905; Wilson 1905a,b). In this case, gender assumptions delayed arrival at the correct model of chromosomal sex-determination, but were eventually routed by the march of empirical investigation. In retrospect, geneticists recognized the likely role of gender assumptions in the initial erroneous theory. However, the quick remediation of the error mitigates the perception that this is a case of gender bias in science.

2. *The assumption that an extra Y chromosome makes males more aggressive*: In the 1960s and 1970s, males with an extra Y chromosome were found

to have a greater incidence of incarceration in security institutions than normal XY males (Jacobs et al. 1965). Males with an extra X chromosome were also found in prisons at the same higher rate (Jarvik et al. 1973). Though XXY men had the same criminal profile as XYYs, XYY men were hypothesized to be extra-aggressive and prone to violent sexual crime, while no link was explored between the X chromosome and aggression (Witkin et al. 1976). The idea of an XYY "supermale" syndrome due to an extra dosage of genes determining male-typical traits flourished for a decade before large-scale genetic epidemiology studies in the late 1970s disproved any association between the Y chromosome and aggression (Witkin et al. 1977). Although the association between the chromosome and the behavior was empirically disproved, the foundational assumption that the Y is the genetic basis of maleness, and thus that an extra Y would constitute an extra "dose" of male-typical behavior such as aggression, was never questioned, and continues to be implicit in much human genetics research on the sex chromosomes today (Page and Lahn 1997; Graves 1998). In this case, local errors introduced by gender assumptions were corrected, leading to the rebuke of the XYY theory of aggression after more than a decade of misdirected efforts and resources. Yet researchers did not recognize their larger assumption equating the Y with maleness as a source of the error. The instigating biasing assumption itself in this case remains unconfronted and continues to influence global research models in the field of Y-chromosome research.

3. *The assumption that the essential sex-determining gene would be on the Y chromosome*: From the 1940s to the early 1990s, researchers assumed that the crucial sex-determining event was the initiation of testes development in the male fetus, and that the sex-determining gene would be located on the Y chromosome (Jost et al. 1953). This culminated in a race to locate the sex-determining locus on the human Y in the 1980s. In 1990, *SRY*, the putative sex-determining gene, was identified on the Y chromosome (Berta et al. 1990; Koopman et al. 1991). Yet this gene did not behave as expected. It did not control or activate a pathway, no gene target was evident for it in the human testes, and it was—uncomfortably for some observers—closely related to an important gene family on the X chromosome (McElreavey et al. 1993; Graves 1995; Just et al. 1995). By the late 1990s, the longstanding model of genetic sex determination—a single "master gene" on the Y chromosome that directs the development of the male gonads and thereby determines sex—had fallen, and was replaced by a view of the *SRY* gene as one among many essential mammalian sex-determining factors involved in the genetic pathways of both testicular and ovarian determination (Vilain 2004). Feminist theories of gender (e.g., Graves 2000, 2002) contributed to the development of this significantly revised genetic theory of sex determination, anticipating the revised model earlier than others and lending intellectual resources, including language and concepts, to the model reconstruction effort. In this case, one set of invisible biases maintained by hegemonic gender ideology was displaced by another set of visible, theorized "biases," or conditioning starting assumptions, in favor of anti-hegemonic gender ideology.

The new set of starting assumptions turned out, in this case, to be more productive for modeling the genetic basis of sex determination (see Richardson 2008).

Each of these briefly-sketched cases is typical of the way in which gender functions in many areas of the biosciences: Gender conceptions are an omnipresent and epistemically relevant source in the theories, models, and descriptive language of research on sex. Yet each case is different, and all stretch beyond simple questions of bias. For instance, it seems that science may be unbiased but sexist (case 1), biased and sexist (case 2), or "biased" and anti-sexist (case 3). These three episodes in the history of twentieth-century sex chromosome genetics demonstrate that gender is not a static source of bias in scientific research, but is instead a highly dynamic and context-dependent dimension of scientific knowledge.

An alternative approach to philosophical gender analysis of science places studies of gender bias within a larger investigation of how gender ideologies interact with scientific knowledge, opening up a more fully naturalized and richer area of philosophical inquiry. Such a project, a more nuanced approach to bias and its role in either inhibiting or developing effective scientific knowledge-producing projects, might be termed *modeling gender in science*. Rather than pursuing the question of gender in science as one merely of biased science, we might model how gendered norms, assumptions, language, and metaphors contribute to scientific theories and models (Haraway 1989, 1991; Keller 1985, 1992; Longino 1990; Rolin 2002). Such questions might also include what constitutes bias, how bias solidifies in a scientific community, whether and when bias has undesirable epistemic consequences, and how and whether it responds to various kinds of challenges.

For feminist philosophers, then, the emphasis on bias is conceptually and intellectually limiting, reducing the scope and philosophical excitement of the gender and science question. Specifically, bias provides a parochial and inadequate framework for constructive philosophical analysis of gender in science. An over-focus on classic cases of bias may hinder deeper probing, systematic characterization, and realistic description of the dynamics of gender in science. While one of the central contributions of feminist philosophy of science, therefore, has been a critique of bias-centric critical approaches to science, feminist philosophers still struggle to communicate this to others and to articulate applied methodologies for moving "beyond bias." A project for the next generation of feminist philosophers of science is to continue to explore, develop, and articulate philosophical frameworks for modeling the interaction between gender ideologies and science—in ways inclusive of, but not restricted to, the question of bias.

4 Conclusion

Feminist philosophy of science has led to improvements in the practices and products of scientific knowledge-making, and in this way it exemplifies socially relevant philosophy of science. Feminist scholarship on science thus presents a worthy thought-model for considering how we might build a more socially relevant philosophy of science—the question posed by the editors of this special issue. In the above analysis of the contributions and challenges of feminist philosophy of science, I have argued that

engaged case study work and interdisciplinarity have been central to the success of feminist philosophy of science in producing socially relevant scholarship, and that its future lies in developing robust and dynamic philosophical frameworks for modeling social values in science.

There continues to be a strong need for public intellectuals who are engaged with science, philosophy, and gender studies who can flexibly mobilize and apply a critical analytical framework for understanding questions at the intersection of science and gender. Biological determinism, for example, retains tremendous ideological power in both public and academic contexts, and there is a continuous imperative to rearticulate and reenergize critical analytical perspectives on science in ever-changing contemporary circumstances. With their rigorous analytical training, deep understanding of the science, and interdisciplinary fluency, feminist philosophers of science are well-situated to engage and uphold this important public intellectual discourse. Feminist philosophers introduce feminist analysis of gender to scientists by intellectually modeling a critical approach to gender assumptions in science. They answer common misconceptions about scientific findings concerning human sex differences. They counter biological arguments used in public discourse to support traditional gender-ideological views of sex and gender roles. Finally, they offer an alternative, multidisciplinary, nonreductionist and multilayered view of how we might understand sex and gender in all of its dimensions. The questions and frameworks of feminist scholarship on science, moreover, extend beyond issues of gender, to analysis of ideology in scientific work on human difference in areas such as race, ethnicity, sexuality, and disability (e.g., Harding 1998; Haslanger 2000; Gannett 2004; Tuana and Sullivan 2007).

The path to responsibly engaged, interdisciplinary scholarship that feminists have carved has at times been an onerous and risky one, at odds with the institutional and intellectual culture of American philosophy. Given the need for and social relevance of their work, it is a worthy exercise to imagine a profession of philosophy in which socially engaged work of this nature is included within the scope of legitimate activities and is an integral part of the training, rewards system, and everyday practices of the discipline.

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