INTRODUCTION

Interdisciplinary Hauntings

The Ghostly World of Naturecultures

> The more enlightened our houses are, the more their walls ooze ghosts.
>
> —Italo Calvino, *The Literature Machine*

> But I almost think we're all of us Ghosts . . . It's not only what we have inherited from our father and mother that "walks" in us. It's all sorts of dead ideas, and lifeless old beliefs, and so forth. They have no vitality, but they cling to us all the same, and we cannot shake them off. Whenever I take up a newspaper, I seem to see ghosts gliding between the lines. There must be ghosts all the country over, as thick as the sands of the sea. And then we are, one and all, so pitifully afraid of the light.
>
> —Henrik Ibsen, *Ghosts*

The woman in a flowing white sari glides by on a dark moonlit night surrounded by a fuzzy eerie glow. The trees rustle gently. A haunting melody plays in the background . . . These were frequent scenes in Bollywood and other Indian movies that I grew up with. Ghosts in Indian movies are always characters whose abbreviated life marks urgent unfinished business—usually characters that are murdered for the secrets they knew or for money, politics, or love. Not able to withstand the injustice of the murder, their ghosts appear at opportune moments in the film, often in song, to bring the past injustice to light. They always appear to those who, while frightened, are willing to listen, investigate, and excavate a gruesome and troubled past. The ghosts by their constant and insisting presence coax and shepherd the slow uncovering of the past, the un-

comfortable but undeniable truth. In the end, the guilty are apprehended and the innocent consigned to eternal heterosexual bliss. The injustice corrected, the ghosts disappear into oblivion with peaceful and satisfied souls.

The realm of the preternatural in Indian culture always annoyed me. It flew in the face of life in postcolonial urban India suffused with an ethos of the secular, rational, and scientific. But in the movies, mythologies, comics, books, and popular culture the living and the dead, the natural, preternatural, and even the supernatural, mingled effortlessly. The film director and writer Ritwik Ghatak has insisted that the realm of spirits, ghost worlds, and reincarnations are quintessentially Indian; to understand India is to understand these worlds. But to my young nerdy science mind, ghosts signaled religious superstition and ignorance—factors that kept India a backward and third world country. Science and technology and the rational worlds they inhabited were the way forward to modernity.

These visions of a science removed from culture, politics, and history were quickly dashed once I was in the hallways of science. It was women's studies that helped me understand that, contrary to my earlier beliefs, scientific culture was not a "culture of no culture" (Traweek 1992). Rather, categories of gender, race, class, sexuality, and nation were everywhere, constantly shaping science, its practitioners, its cultures, and scientific knowledge. Over the past decade I have worked to translate this insight and my training in women's studies and the biological sciences into a combined practice—moving a disciplinary world of natures and cultures into an interdisciplinary one of naturecultures.

Studying naturecultures, however, poses a problem of methods. In traditional academic configurations, one studies the natural world by using methods of the natural sciences and the cultural world using methods from the humanities and social sciences. But how does one study a naturecultural world? How do you develop a practice where nature, science, *and* culture matter (Fausto-Sterling 2003)? The past three decades have yielded a wealth of discussion and debate about methodologies, ontologies, epistemologies, and methods in the feminist studies of science (Ahmed 2008, Alaimo and Hekman 2008, Barad, 2007, N. Davis 2009, Haraway 1988, 1997, Harding 1986, 1991, Hird 2004, Kirby 1997, Longino 1990, Roy 2004, 2008, Wilson 2004). One common theme spans these explorations—it is that knowledge is not out there to be discovered or is inherent in any scene or object, but that knowledge generation is an active engagement. Knowledge comes "to be" through complex processes including the scientists and their objects of studies, both located in their material, historical, geopolitical, economic, and naturecultural contexts (Stengers 2011, Barad 2007, Longino 1990).

For example, let us consider the famed and long-enduring debate on nature versus nurture. Recent scholars posit that this is a false binary. The phenotype, or the material body, emerges through the complex actions of nature *and* nurture. It is not as though nature acts through nurture or that nurture nurtures a nascent "natural" organism, rather that organisms are co-constituted and co-produced by nature *and* nurture, genes *and* their environments. As Evelyn Fox Keller maintains, it is not possible to apportion the percentage that we can ascribe to nature or nurture, although biologists and social scientists try mightily to do so (Keller 2010). Co-constitution and co-production suggest an inextricable interconnection (Reardon 2001). Reducing them into some original constituency misses the co-constituted knowledge of how matter comes "to be." We have to find a way to study them simultaneously. Indeed, the sooner we can give up the binary of nature and nurture and find new vocabularies to study the emergence and development of life, the better. A lofty goal, but a worthy project for feminist science and technology studies. Using the resources of the natural sciences, social sciences, and the humanities and arts, I narrate attempts at just such interdisciplinary naturecultural practices.

In attempting the bridgework, the more I tried to bring the worlds of women's studies and the sciences together, the farther they seemed to drift apart. Bruno Latour's formulation on disciplinarity is useful. In exploring the practices of modernity, he describes two sets of impulses (Latour 1993b). First, the "work of purification," whereby we create two entirely distinct ontological zones: that of the nonhuman/natural world on the one hand, and that of human/cultural world on the other. Alongside this work of purification, Latour also elaborates a second set of practices, namely, the "work of translation," which creates mixtures between the worlds/hybrids of nature and culture. Such is the paradox of the moderns, he argues; "the more we forbid ourselves to conceive hybrids, the more possible their interbreeding becomes" (Latour 1993b: 12). In retrospect, my task was more challenging because neither zone was all that stable. On the one hand, we carry on the work of purification in the academy by creating different sets of disciplines, tools, and methods and reify the separation of the worlds of human and nonhuman, nature and culture. On the other hand, this work of purification *creates* hybrids of all kinds between nature and culture. After all, while the staging of science might imagine pure scientists studying a pure nature, a naturecultural world is constantly making and remaking itself (Stengers 2011).

Feminist science and technology studies (FSTS) reveals a history of knowledge teeming with the interwoven worlds of science and politics, of biology and society, of nature and culture. Historians have argued that scientific knowledge

should be understood within its historical, political contexts. After all, much of the scientific knowledge that we find questionable today (such as phrenology or craniometric studies about sex and racial differences or diagnosis of hysteria or neurasthenia, to just name a few) was widely accepted among the scientists of its times. This was "good" science done by "respected" scientists and accepted by their peers. As Nancy Stepan (1982) has argued in tracing the idea of "race," "the scientists who gave scientific racism its credibility and respectability were often first-rate scientists struggling to understand what appeared to them to be deeply puzzling problems of biology and human society. To dismiss their work as merely "pseudoscientific" would mean missing an opportunity to explore something important about the nature of scientific inquiry itself" (xvi).

As history reveals, scientific findings, and indeed all knowledge production, are emergent within the contexts of their production. Unless we are prepared to claim that contemporary science is inoculated against social and historical influences (surely a fanciful claim), it behooves us to be reflexive when it comes to our own knowledge production practices. Thus as science and technology studies has suggested, if science is "constructed," and we come to understand its workings, it can also be "reconstructed" (Woodhouse 2005, Campbell 2009). That is my goal in this book: to imagine a feminist reconstructive project for experimental biology.

What do I mean by "feminist"? Feminism today has expanded beyond a focus on women, to how material bodies, institutions, and structures are gendered. Feminists also recognize that woman is not a universal monolithic category, but always intertwined with other social categories such as gender, sexuality, race, ethnicity, class, and nation since women's experiences are shaped by their multiple social locations and identities. Thus, "feminist" means not just exploring women or gender, but recognizing the co-constituted meanings of categorizing human populations. We need to focus on the process of knowledge production, not just the content. Feminist historians of science also demonstrate that science has been central in the invention of biological categories such as sex, gender, race, class, nation, and sexuality, and subsequently reifying social prejudices in the inferiority of women, people of color, colonized, poor, or homosexuals. Historians remind us to examine the process of *how* this knowledge came to be. Such work requires critical reflexivity among knowledge producers. The goal of feminist science studies is not to produce knowledge that is prefigured in what it says about women or people of color or queer communities or third world nations (H. Rose 1997). *The goal is to develop an experimental practice and method that does not overdetermine or prefigure its conclusions.* The tensions and challenges of reflexivity and situating knowledge

while simultaneously opening up new possibilities is the joyful acrobatics of academic play, one we must embrace with imagination and gusto (Stengers 2011). How do we develop such a reflexive and reconstructive project for experimental biology?

I am deeply influenced by Helen Longino's proposal that "we focus on science as practice rather than content, as process rather than product; hence, not on feminist science, but on doing science as a feminist" (Longino 1989: 47). Longino's rejection of a content-based approach comes from the dangers (surprisingly frequently in the literature) of conflating "feminist" with "feminine." In asking the question "Can there be a feminist science?" she argues that "if this means: is it in principle possible to do science as a feminist?, the answer must be: yes. If this means: can we in practice do science as a feminist?, the answer must be: not until we change the social and political context in which science is done" (Longino 1989: 56). I wholeheartedly agree. The challenge then is not a pointless battle between the irreconcilable frames of objectivity and social construction, but how to better understand the tensions between objectivity and belief as a necessary part of science and as central to the practice of science (Stengers 2000). In what follows in this book, I chronicle my attempt to craft a scientific practice that embraces the tensions between being a feminist (with all the commitments that entails) and being a feminist who recognizes the collusion between scientific knowledge and categories of difference. I do so by examining a central concept in both biology and women's studies—variation. I explore the histories and political contexts of the scientific production of the theories of variation and how they are deployed in three different sites: morning glory flower color variation, invasion biology, and women in the sciences. Since our focus must be not only on the resulting knowledge but also the practice—a contextual account of knowledge and its naturecultural co-production—this book chronicles the process of such work and its subsequently reconstructive imaginations. The binaries of nature and culture are deeply embedded in our academic institutions; in our disciplinary formations; and in our knowledge-gathering epistemologies, methodologies, and methods. To refuse this binary and produce knowledge about a naturecultural world is neither simple nor easy—the walls of disciplinary thinking, institutional barriers to publishing, finding jobs, and promotion and tenure are constant. Yet, I believe it is dangerous to suggest an easy reciprocity between nature and culture, between humans and nonhumans; our knowledge production has been far too mediated by the politics of the academy. While we can argue that science is in many places (Roosth and Schrader 2012)—in bacteria, plants, and animals—I am interested in exploring what is possible within the structures of academic science, and

take seriously the experiences and agency of the practitioners of that science. Similarly, while science occurs in many sites such as in indigenous knowledge systems, or kitchen science, or DIY science, this book is an attempt to open up the epistemic authority and expand the practices and epistemologies of what we call "normal science." This book thus chronicles what is possible within the geographies of our academic institutions today while it imagines the fertile possibilities of a world not bounded by disciplinary logics.

The Ghostly Worlds of Naturecultures

As William Faulkner reminds us, "The past is never dead. It's not even past" (Faulkner 1951: 80). With this lesson firmly in mind, I began my forays into the interdisciplinary world of naturecultures. At first, I did not see the ghosts, not at all. Now I cannot believe that I ever missed them! Today they stand out in the landscapes around me. The many ghostly figures among the morning glories, the apparitions among the changing landscapes, and the luminous figures rendered invisible by the histories of science. I now see the hauntings, the ghostly apparitions, the shadowy silhouettes of our past appearing all around me, staring at me, insisting on being seen.

As I perched on the naturecultural bridge, the past and the present came clearly into focus and I began exploring. I began with tracing the history of the question of variation in evolutionary biology and suddenly new lines of connection came into view . . . And they appeared—the ghosts among the morning glories in North Carolina and the landscapes of Southern California and in the histories of women in the sciences. Tracing the history of flower color led me to the history of evolutionary biology, and the specter of eugenics emerged. In examining the landscape of Southern California and tracing the idea of the "native" in the history of ecology, the ghosts reappeared. And with the ghosts, returned the specter of eugenics. As I examined the history of women in the sciences, I encountered the *biopolitical scripts* (Takeshita 2011) where some bodies were deemed gifted with intellectual capabilities while others were relegated to kitchens, homes, wombs, menial tasks, or asylums. Again, *eugenic scripts* shaped biographies of those deemed science worthy and able "modest witnesses" (Haraway 1997). And the ghosts reappeared. In Bollywood tradition, these were the ghosts of the violently dispossessed, the unrealized talents, the forgotten brilliant, the sterilized, the mutilated, the unacknowledged, the ignored, the marginalized, the famous, and the common—whose lives were abbreviated by a brutal history, rendered invisible, whose genius was never realized, and whose voices were silenced by a disciplinary history devoid of people.

Who were these people, I wondered? What were their connections to the theories and methods I studied in my courses in biology? Why were they returning to haunt me? The Bollywood memories came back and I succumbed to the lure of the ghosts and the ghostly dispossessed. I began to scour the history books, to unearth the history I had never been taught. To my shock, I discovered that these were rather well-researched histories within the history of biology, just ones not taught to biologists. Similarly, women's studies did teach about the horrors of eugenics, but disciplinary silences never considered morning glories or the ecological landscapes as worthy objects of feminist inquiry. It was no wonder that these connections were not readily apparent—disciplines were constructed precisely to obscure their connections. With their mutually exclusive disciplinary objects firmly in place, the biological sciences and women's studies can go about their disciplinary pursuits undisturbed. Getting past the disciplinary silences, I dug in, and so emerged this book.

At the heart of all three of these sites—morning glory flower color variation, invasion biology, and women in the sciences—was the central question of variation. Related to variation are more popular terms: *diversity* and *difference.* How should we understand variation, diversity, and difference? Why is variation such a central question that it reverberates through the history of evolutionary biology *and* women's studies? Variable or not—what is the power in the idea? The central argument of the book is that disciplinary logics make invisible the political (eugenic) questions that are central to the question of variation. A naturecultural framework, however, makes visible why the question of variation is so central and long enduring in the cultural and natural worlds, and why the stakes are so high. Indeed, tracing the genealogy of the idea of variation reveals its fundamentally recursive structure—we return to the same question of variation again and again in the history of biology and politics. I have modeled this recursivity in the very structure of the book, as we revisit its persistence through examining the idea of variation through multiple sites in science—its genealogy, its geography, and its biography. The ghosts and their hauntings link these varied sites and show their naturecultural interconnections—it is indeed the same ghosts that haunt the interstices of our genealogies, geographies, and scientific biographies. Questions of genetic variation in human and nonhuman organisms are deeply linked to questions of diversity and difference in human populations steeped in tortured histories of slavery, colonialism, and genocide. *A naturecultural analysis reveals that the question of variation is fundamentally about power—the politics of life and death.* The seemingly innocuous history of genetic variation holds within it the countless bodies of the dead, the mutilated, the tortured, the irredeemable, the unwanted, as well

as the brilliant talents that have gone unrecognized and unacknowledged—all those unknown, forgotten humans relegated to the rubbish heap of history. It is these wounded souls, these tortured histories, that roam the interstices of the question of variation. These are the ghosts of naturecultures . . .

Genealogies of Feminist Science and Technology Studies

Historians often date the origins of modern FSTS to Carolyn Merchant's 1980 book *The Death of Nature* (Schiebinger 2003). In a recent retrospective essay, I used "moored metamorphoses" as a metaphor to capture both the development of the field of FSTS as well as my own intellectual transformation (Subramaniam 2009). FSTS is a difficult field to define, as it is a heterogeneous and amorphous body of work that has emerged and grown organically rather than a field with consensus or cohesion. Its practitioners range from scholars in interdisciplinary programs such as women's studies, gender and sexuality studies, science studies, cultural studies, and visual studies to those located in traditional disciplines across academia. After early practitioners articulated and developed the theoretical foundations of a critique of the sciences, the field exploded. In many ways, I consider myself incredibly fortunate to have discovered the field when I did. When I knocked on the doors of women's studies, my mentors were able to introduce me to a vibrant body of work on feminism and science. The pioneers of the field had already established a foundational set of analyses, what came to be called the *feminist critiques of science.* The critiques made an important shift from questions of women *in* the sciences to articulating the relationship of gender *and* the sciences. The early works of Birke, Bleier, the Brighton Women and Science Group, Fausto-Sterling, Hammonds, Haraway, Harding, Hubbard, Keller, Longino, Lowe, Martin, Rose, Rosser, Schiebinger, Spanier, and Tuana (listed here in alphabetical order, not in order of importance) elaborated why women, gender, and feminism mattered in the production of scientific knowledge. The central critiques were directed at biological determinism, scientific objectivity, and assumptions about value neutrality, reproduction, and the labor of women; gendered images and language; challenging the boundaries between nature and culture; the role of capitalism; and the politics of knowledge and its production (Subramaniam 2009). From a core set of critiques, the field has exploded vertiginously across disciplines and interdisciplines, taking on a wide range of topics in almost every discipline with a vibrant and striking heterogeneity. In many ways this is the strength and promise of FSTS—there are no departments, journals, an-

nual conferences, or organizing structures that bind or define the field. There is no established canon. Contributors have come from a wide range of places and from unconnected disciplinary and interdisciplinary origins and paths. In examining syllabi in the field, there appears no set of canonical readings that typify the field. While it is now difficult to keep up with the literature in the field, there is also something exhilarating and dynamic about the field's fluidity. Recognizing the dangers of unitary genealogies and citational practices (Hemmings 2011) and saluting this rich and heterogeneous history, I offer no single genealogy to the field.[1] Others have attempted to characterize it (Keller and Longino 1996, Lederman and Barsch 2001, Mayberry et al. 2001, Schiebinger 2003, 2008, Tuana 1989, Wyer et al. 2008).

Looking across these multiple genealogies, most recognize three sites or levels of analysis (Schiebinger 2003). First is the body of work on women *in* the sciences that chronicle the history, sociology, biographies, and activism of women scientists. Central to the field in its long and enduring history is confronting questions about whether variation in who practices science is good, and answering the question in the affirmative, the field has developed strategies to address women's underrepresentation. Second, scholars have organized around studies of the "cultures" of science (Knorr Cetina 1999, Latour and Woolgar 1986, Noble 1992, Traweek 1992, 1993). Women's participation in science and the contexts of knowledge production depend on the cultures scientists inhabit. Scholars have shown that science emerged as "a world without women" and that this history of male domination has fundamentally shaped the early cultures of science and lives on in contemporary scientific culture (Noble 1992). Science indeed presents itself as the ultimate privileged site immune to its unique history, geography, or genealogies. Scientific culture understands itself as a "culture of no culture" (Traweek 1992). Challenging such a view, feminists argue that histories of sex, gender, race, class, sexuality, and nation have deeply shaped and continue to shape the cultures of science. Finally, in addition to the practitioners of science and the cultures they work in, scholars have focused on the production of scientific knowledge. Here cultural critics have documented the myriad ways in which cultural understandings and mores of sex, gender, race, class, sexuality, and nation have historically shaped and continue to shape scientific knowledge. This work has motivated philosophers of science to examine scientific epistemology, systematically dismantling claims of objectivity and value neutrality, and, finally, proposing alternate epistemologies and methodologies for practicing science informed by feminist studies.

Feminist studies, like science and technology studies (STS), emerged from social movements committed to the political struggles of marginalized groups

and activist struggles for a more just and inclusive world (Campbell 2009). Science, a powerful arbiter in the world, has been central to these histories of inequalities (and indeed also in their resistance). Despite the emergence of FSTS within women's studies, the field has yet to embrace the power of its own transformative critique. Women's studies remains firmly grounded in the humanities and the social sciences, and within women's studies, the sciences at best endure as a site of oppression and need for critique. This book builds on this rich legacy of FSTS. I approached this field as an experimental biologist interested in what feminism had to offer science. I soon discovered that *if science was constructed as a world without women, women's studies was constructed as a world without science.* Developing an interdisciplinary life across these fields has meant rethinking them both. A daunting task! This book is about this journey, engaging with the personal, the cultural, and the institutional, all critical to the project of knowledge construction.

In exploring the history of variation, the book argues that western societies (at least since Darwin) have struggled with biological questions of variation alongside political questions of diversity and difference. Nations and scientists aspiring to produce the "good society" engaged the sciences in that mission. But what is the "good society"—a diverse one with a multitude of people or one where only the best and the brightest reproduce to take us to new heights? These debates have haunted us for centuries. Science is one site in which these struggles with the interests of power are evident. These contentious processes, their histories and contexts, are often erased and scientific theories rendered "objective" with epistemic purity and claims to political and value neutrality. Delving into these histories reveals the profound debates around eugenics, about desirable and undesirable bodies—those doomed to sterilization, enslavement, or colonization or deemed perverse, deviant, pathological, or deficient. These histories, I argue, are evident in each of the three case studies, just under the surface. While we may debate selection pressures in evolutionary processes, or the eradication of invasive plants, or the wisdom of recruiting more women into the sciences, the spirit of the dreams of what we mean by a "good society" is at the heart of these debates.

In tracing the central and critical idea of variation in the history of ecology and evolutionary biology, I argue that the concept is one that connects biology and women's studies and the history of ecology and evolutionary biology. Comprehending these interconnections is central to understanding how the vocabulary of variation, diversity, and difference emerged and persists in both fields. I do this by exploring the idea of variation in three sites in three parts of the book—on genealogies, geographies, and biographies. I explore how varia-

tion is understood scientifically, is transformed geographically, and is embodied biographically. In part I, "Genealogies of Variation," I trace the idea of variation and the shifting understanding of its significance in the field of evolutionary biology. I explore how the idea emerged within particular political and economic contexts and has come to shape discourses on diversity and difference today. I excavate the centrality of eugenic scripts in our ideas of variation, and note the dizzying array of scientists who have participated in the eugenic project. I revisit my field experiments on flower color variation and reflexively examine how feminist studies of science can help us critique its goals, methods, and experiments. I suggest alternate ways in which morning glory flower color can and should be studied. I end with using fiction to imagine anew.

In part II, "Geographies of Variation," I use invasion biology as a site to examine how science theorizes plants and animal geographies, especially how nativism and nationalism shape ideas of belonging. It is no accident, I argue, that along with a panic about foreign plants and animals is a profound panic about foreign peoples as well, a panic that is distinctly gendered in reproductive fears of proliferation and miscegenation. I argue that this panic misplaces and displaces anxieties about globalization, labor shifts, and a fast-changing world onto a problem about the geographic origin of species. What is obscured by such panic are the economic and political interests that have ushered in large-scale environmental shifts through unregulated and large-scale overdevelopment. Drawing on four key moments in the past ten years, I develop a recent *bio*graphy of the United States, a nation of interspecies migrants. I also examine collaborative experiments on the ecology of invasion biology. How easy is it to incorporate feminist, political, and activist concerns into experimental practice? I explore both the challenges and the possibilities. Finally, in a meditation on alien-ness, I examine my own standpoint as a foreigner in the United States studying foreign plants and animals and explore how these alien and kindred subjectivities may be a rich source of knowledge and meaning making.

Finally, part III, "Biographies of Variation," traces the case of women *in* the sciences and how ideas of variation and especially debates around them have shaped the histories of women participating in the sciences. The eugenic scripts that emerge in excavating a genealogy of variation reappear in recurring debates about women's intellectual and physical difference from men, a difference constructed against a western-white-male-as-norm backdrop. Rather than disrupting the gendered and racialized nature of science, programs for women in science largely focus on equity and parity in accommodating women in the structures of science rather than transforming science. The exclusive focus on increasing numbers of women has led to helping women achieve science's idea

of a scientist rather than disrupting such normative ideals. Even transformative efforts such as female-friendly policies constructed around demands of pregnancy, motherhood, and family reinforce essentialized ideas of women, highlighting women as exceptional rather than transforming the normative ideals of science. Through biographies of scientists, I explore how FSTS can help move us beyond an equity feminist approach to women in the sciences.

From Variation to Difference to Diversity: Studying Naturecultural Worlds

Variation, diversity, difference—these are three central, critical, and foundational concepts that span women's studies *and* biology, key conceptual categories that permeate and bind the interstices of these interdisciplines. While the term *variation* sounds innocuous, scientific theories of variation come from contestations of very particular variation in humans—of sex, gender, race, class, sexuality, and nation—variation that was understood in a political syntax of its times. These histories have shaped and been shaped by science and are indeed constitutive of science. These were also the critical concepts and ideas that repeatedly emerged in my work on morning glories, invasion biology, and women in the sciences. At first I thought the overlap was fortuitous, but I now understand that such transdisciplinary convergences are never accidental. Instead, the idea of variation is deeply connected to varied sites.

In evolutionary biology, variation is the "stuff" or raw material of evolution. Starting with Darwin (and indeed before), naturalists recognized patterns of similarities and differences in organisms. Why such a wide variety of organisms, and why are some more similar to each other than others? For modern evolutionary biology, Darwin is key. Darwin, it is argued, moved us from earlier typological thinking where individual organisms were seen as varying ever so slightly from an ideal form, be they Plato's "ideal types" or Aristotle's essentialism (Mayr 1973, Sober 1980). Rejecting a metaphysical ideal type, Darwin emphasized the ontology of concrete things (individuals) and the ways in which individuals varied ever so slightly from other individuals (Ghiselin 2005). This move from metaphysics of "typologies" to an empirical science of variation or "populations" is a key conceptual and epistemological shift of Darwin (Mayr 1973, Sober 1980, Grene 1990). Scientists developed empirical categories and methods to measure variation. While Darwin himself was deeply steeped in ideas of gender, race, and nation of his time (Gould 1980, Hubbard 1990), Darwinism opened evolutionary biology and the development of theories of evolution to the powerful forces of social Darwinism and the politics of gender,

race, class, nation, and sexuality of nineteenth-century Britain. Science—its theories, methods, and knowledge—emerged as a critical site where politics and ideologies of difference were encrypted into the very foundations of the field. As the field emerged, physical, behavioral, and intellectual differences between groups were biologized—from differences in skeletons, skulls, metabolic systems, and reproductive organs to traits such as intelligence, feebleminded-ness, pauperism, and alcoholism (Allen 1996). At the heart of this ideological project rested the logic of eugenics. If those born "good in stock, hereditarily endowed with noble qualities," could be encouraged to breed, as Francis Galton, Darwin's cousin and the father of eugenics, suggested, the human race could be improved. Concurrently, preventing the "bad stock" from breeding could hasten improvement (Allen 1996). The purpose of eugenics, Galton wrote, "is to express the science of improving stock, which is by no means confined to questions of judicious mating, but which, especially in the case of man, takes cognizance of all influences that tend in however remote a degree to give the more suitable races or strains of blood a better chance of prevailing over the less suitable than they otherwise would have had" (qtd. in Allen 1996: 23).

To analyze the large volumes of data that emerged, new mathematical and statistical techniques were needed. Thus the field of biometry emerged. Biometrics was "generated as a toolbox for eugenics, as a collection of measurements of characteristics and correlations for the analysis of inheritance" (Louçã 2008: 655). Biometry was not a field that emerged separately and was then applied to the eugenic project; rather, it emerged to expressly aid the eugenics project. The foundations of eugenic thinking, its methodology, and its theories and statistical modeling are thus deeply indebted to the innovations of biometry and its "scientific form of social Darwinism" (Norton 1983). Eugenics was also a culture, providing a bridge between different fields, exerting a powerful influence for defining an agenda for biology and the social sciences where they would inform each other. "Statistics was the language used for that communication and it was a new language—society and not only individuals mattered" (Desrosières 1998: 68, Louçã 2008).

With the motivations of a eugenic project, biologists ventured into large experiments on measuring various characteristics and developed the statistical techniques to evaluate the patterns of variation. Not surprisingly, differences between various groups emerged. Historians have documented the ways in which some populations emerged from these efforts as superior to others (Anderson 2006, 2008, Birke 1999, Bleier 1984, Fausto-Sterling 1985, 1995, Hammonds 1999, Hammonds and Herzig 2009, Haraway 1989, 1991, Harding 1993, Hubbard 1983, 1990, Markowitz 2001, Philip 2004, Prakash 1999, Raina and

Habbib 2004, Reardon 2005, S. Richardson 2012, Sayres 1982, Schiebinger 1989, 1993, Stepan 1985, Terry 1999, Verran 2001). Thus new ontologies and the "logics" of superior sexes, races, nations, and sexualities emerged, and these drew their authority from the growing power of "science." It is critical to recognize that these ideas of difference were "biological" differences and believed to be innate, shaping the character and biological potential of individuals within populations. These were claimed to be essential characters of groups, not constructed or easily mutable. Indeed, these logics took hold in the logics of colonialism and in the political cultures of colonial powers as well as members of the colonies. Thus seemingly innocuous ideas of variation were converted to profound and political ideas of difference between various groups at various times in history—men versus women, whites versus blacks, colonial powers versus the colonies, heterosexuals versus homosexuals, elite versus working poor (Birke 1999, Bleier 1984, Briggs 2002, Hammonds 1999, Hammonds and Herzig 2009, Haraway 1989, 1991, Harding 1993, Hubbard 1983, 1990, Markowitz 2001, Philip 2004, Prakash 1999, Raina and Habbib 2004, Reardon 2005, Rubin 2012, Sayres 1982, Schiebinger 1989, 1993, 2004, Stepan 1985, Terry 1999). *The benign language of variation is thus converted into the profoundly political language of difference.* Indeed, difference now stood for the superiority of some groups and the inferiorities, pathologies, deviance, and perversions of others. The differential biological potential of different groups and arguments about biological difference (rather than social inequality) emerge as the main cause for social problems of the superiority and inferiority of various groups. Reading eugenics through a history of sex, gender, race, class, sexuality, ability, and nation reveals the profoundly political project that it was. In uncovering these deeply political histories, and tracing questions of identities and institutions, I discovered a profound logic of difference. This logic is articulated through policies on individuals as well as institutions; the logic of difference also disciplines institutions to act in particular ways (Foucault 1977). Darwin moved us from one kind of essentialist thinking in typologies, but the shift to variation and population thinking ushered in a new essentialism of identity—of sex, race, class, sexuality, nation, and ability—that lives on in contemporary politics (Gannett 2001, Grene 1990). Essentialism has a long legacy of being dangerous for the "other," and locating human capacities and capabilities in the immutable body was a profound development (Said 1979).

Drawing on the work of historians and philosophers of biology, feminist critics of science have argued that the institution of science reified social power and privilege into claims of natural and biological difference. As identity-based movements reclaimed the power of the margins—of femininity, blackness,

queerness, disability, and third world nations—a negative politics of difference was translated into a positive politics of diversity. Thus, diversity emerged as an aesthetic of celebrating cultural variation and expressions of cultural difference within liberal discourse (Eriksen 2006). New social movements dedicated to multicultural and inclusive visions converted difference into a celebration of diversity. The problem, they point out, is not that groups are different from each other. Rather, the problem is in judging and evaluating groups whereby some group differences are translated into the superiority of one group over other groups (Lorde 1984).

Many scholars have argued, however, that contemporary work on diversity, rather than questioning differences, often "mirror" and reinforce them (Baez 2004). Indeed, as Chandra Mohanty maintains, in practice, diversity has become a discourse of "benign variation, which bypasses power as well as history to suggest a harmonious empty pluralism" (Mohanty 2003: 193). Diversity in its recent institutional incarnation has been utterly domesticated and depoliticized and largely seen as "good" because it has lost its political roots of structural issues of sexism and racism. Diversity is used in diverse ways to mean very different things (Ahmed 2012), reminding us that categories are contextual and unstable, and deeply political. As Omi and Winant claim, identity categories like "race" do not have content by themselves. These categories, emerging at particular historical moments, were mobilized toward clear political and economic ends. Race is a "formation" through the complex and shifting sets of political projects that organize human bodies and social structures in the aid of particular agendas (Omi and Winant 1994). The challenge then is to explore how and why our discourses of difference organize the category of difference within particular configurations of power and how they shape individual experiences and attitudes (Baez 2004). How were ideas of variation translated into the violence and virulent politics of the inferiority of difference in sexes, races, classes, nations, sexualities, and abilities? Through the development and use of Darwinian natural selection, variation was translated into difference, and into the conceptual and political landscape of sex, gender, race, class, nation, sexuality, and ability so familiar to us today. Population thinking retains and refigures inequalities in new "scientific" ways, obscuring their political genealogies (Gannett 2001, Grene 1990).

Intersections of Interdisciplinarity

In examining feminist histories of identity categories, two factors are striking. First, interdisciplinary explorations across biology and women's studies reveal

profound intersections in the production of difference and identity. Intersectionality is most often defined as "the relationships among multiple dimensions and modalities of social relationships and subject formations" (McCall 2005: 1771). While I am aware of the contested histories and critiques of the idea of intersectionality, its multiple meanings and heterogeneous uses, its peculiar institutionalization, its intellectual and political mobilization, and the fears that its depoliticization and domestication in the academy have foreclosed its more radical potential (Crenshaw 1991, Hammonds 1994, Hancock and Yuval-Davis 2011, McCall 2005, Puar 2007, 2012, Nash 2008, 2009, Yuval-Davis 2006), my ambition is more particular and rather modest.

I use the term *intersectionality* to highlight the creation and naming of particular material bodies—such as the "heterosexual black slave woman" or the "Oriental woman" or the "white homosexual man"—produced through the histories and theories of science. Indeed, understanding intersectionality as a process emerging through the institution of science and the material production of different bodies has not been adequately explored or theorized (Collins 1999).

Second, the histories of sex, race, sexuality, class, nation, ability, and various categories of identity are not mutually exclusive and did not arise independent of each other. By this I mean that while new social movements have highlighted universal identity categories such as woman, black, colonized, LGBTQI, queer, disabled, or third world (and thus created their normative counterparts in man, white, straight, able-bodied, and first world), historians of science suggest otherwise. Rather than emerging as universal categories, identity categories appeared through material bodies in very particular and deliberate ways. The politics of biological differences created hierarchies of difference—of nuanced and intersecting biological potentialities of various material bodies.

While we often view categories such as sex and race as empirically and biologically distinct, they are murky. Perhaps the best researched and most written about is the case of the South African black woman Sarah Bartmann, or the "Hottentot Venus," who was paraded across Europe as a scientific curiosity and whose body was probed and catalogued during her life and beyond. Her open sexuality and unfeminine behavior provoked anxiety among white western scientists, who ultimately pathologized this body, which destabilized white male superiority at home and abroad (Adams and Pigg 2005, Stoler et al. 2008, Takeshita 2011). Much has been written about this case, and the analyses powerfully and systematically present how the colonial scientific authority systematically "produced" and created the inferior colonized "savage" black African woman's body (Fausto-Sterling 1995, Gilman 1985, Magubane 2012,

Sharpley-Whiting 1996, Takeshita 2011). The extraordinary scrutinizing of Sarah Bartmann that endlessly chronicles the intense racism and sexism that accompanies her life also redeploys racism and sexism in its retelling, cautioning us that revisiting history can never be innocent (Fausto-Sterling 1995). Nancy Stepan (1986) has pointed out that the historical record shows repeated and direct analogies made between identity categories. For example, she demonstrates how the race-gender analogy was used in the nineteenth century to claim women's smaller brains and protruding jaws as evidence of their evolutionary inferiority to European men. She describes a process where "by analogy with the so-called lower races, women, the sexually deviate, the criminal, the urban poor, and the insane were in one way or another constructed as a biological 'race apart' whose differences from the white male, and likeness to each other 'explained' their different and lower position in the social hierarchy" (Stepan 1986: 40–41). By the mid-nineteenth century, racial biology became "a science of boundaries between groups and the degenerations that threatened when those boundaries were transgressed" (Stepan 1985: 98). In a similar vein in "Pelvic Politics," Sally Markowitz argues that the very idea of sex differences emerged from racialized meanings of bodies. She traces how the category and ideology of sex/gender rests "not on a simple binary opposition between male and female but rather on a scale of racially coded degrees of sex/gender difference" (Markowitz 2001: 391). Rather than a universal or species-wide man or woman, evolutionary biology produced the "manly European man" and the "feminine European woman" as evolutionary types that mark the pinnacle of a hierarchical project of race (Markowitz 2001: 391). The very categories of identity emerge as co-constituted and co-dependent intersectional categories. Thus, characteristics like femininity are racialized themselves in the historical record; "femininity" could not be assumed to be a characteristic of *all* females (Schiebinger 1993). The distinct categories of sex and race cannot be presumed to be historically evident. Cathy Gere (1999) demonstrates this in a paleontological study where scientists confronted fossils with two distinct sizes of skeletons. Do these represent a sexually dimorphic population with differently sized males and females or two differently sized populations, one large and another smaller? She argues that only in making assumptions of racial and sexual differences can such a history be interpreted. Assumptions about race and sex are deeply intertwined.

What emerges from such different ontologies of race and sex is a profound political "logic of difference" that comes to underlie the foundations of medicine and science in creating racialized and gendered bodies (Hammonds 1999). For example, in tracing the origins of gynecology, historians have shown how

racialized understandings of black women as "strong" (as opposed to elite white women's fragility) translated into an extraordinary biological capacity to bear pain. Thus for the father of gynecology, Marion Sims, "blackness defined what pain meant for these women, just as white womanhood defined his understanding of white women's pain experience" (Wanzo 2009: 159). Such logic of difference permeates nineteenth-century racial taxonomies and racial differences in creating what has been called the "medical plantation" (Dudley 2012). It is from such logics that black women's bodies were subjected to vaginal surgeries without anesthesia (Wanzo 2009). These logics presented unique paradoxes. Black women's difference in their high threshold of pain provided the logic for surgery without anesthesia while at the same time their sameness assumed knowledge about their bodies to be transferable to white women. What is striking and irrefutable but unsurprising about this history is that the logic of difference always benefits the elite and powerful at the expense of the poor and marginalized.

The histories of eugenics and gynecology amply demonstrate the profound consequences of the logics of difference—in the untold pain and suffering for those deemed inferior and/or expendable. The political nature of the scientific knowledge becomes particularly clear when we trace how such knowledges were put to use. For example, in the late nineteenth century, educators such as Kenneth Clarke warned against the higher education of elite white women (Sayres 1982). Drawing on biological theories that women's biology necessitated energy for reproduction, they argued that women's intellectual development would necessarily come at the cost of reproduction. Drawing on racist and xenophobic arguments, Clarke argued that if elite white women were given access to higher education, their low fertility would lead to a nation overrun with immigrants. Women's access to higher education was thus opposed on biological grounds to save the elite white race (Sayres 1982). If indeed such biological theories were deeply believed, we see no evidence of mass campaigns for the education of immigrant women, poor women, or women of color whose purported reproductive activity yielded such race panic!

The power of the logic of difference underlying scientific claims of the varying capacities of human bodies lies in the politics of biological determinism. Scientific claims of biological differences were not understood to be mutable but rather fixed and determined by biology. The foundational work in FSTS has documented how scientists "produced" biological differences of gender, race, class, and nation—claims of anatomical difference, physiological differences, as well as differences in behavior, temperament, and intellect. These biological differences are naturalized by culture. Feminists have amply demonstrated

the tautological arguments and the evolving circular logic as knowledge travels between the natural and cultural worlds. Fausto-Sterling (1987) sums it up well in the title of one of her essays: "Society Writes Biology/Biology Constructs Gender." Biology and society, nature and culture, are inextricably intertwined as culture constructs ideas of gender and biology naturalizes those societal ideas and mores. Cultural and social norms are now rendered scientifically objective and biologically immutable.

Given these histories, understanding intersectionality as a material-semiotic process through which bodies—endowed with sex, gender, race, class, sexuality, nation, and ability—are produced is critical. The metaphor that best describes this history is the game of *Jenga.* Dismantle any one of these blocks/categories, and the whole edifice comes crumbling down. Feminist and antiracist scientists have valiantly challenged simplistic notions of sex and race (and we will see more of this history throughout this book). Scientific theories are literally constituted through the material politics of privilege and marginalization, through the practices of determining who reproduces and who is sterilized, of who is welcomed into a nation or kept out of its borders, of who counts as an "individual" in the eyes of the nation honored with the right to vote, property, industry, or representation. Scientific politics help constitute social politics. It is at these intersections of biology and politics that the ghosts of naturecultures come tumbling out.

THE QUESTION OF GENRE

Narrative is at the heart of this book—narratives that the sciences and humanities have come to tell about the world. One of the striking patterns that emerged in telling the story of variation is its recursive structure—we encounter our struggles with the question of variation again and again. This pattern of recursion structures the book in the ghosts that haunt my narrative again and again. This is rather fitting as science was once a branch of philosophy and great scientists such as Galileo and Newton thought of themselves as "natural philosophers." Given that the term *scientist* was coined as recently as 1834 by William Whewell, it is rather extraordinary how deeply and stubbornly the idea of science as divorced from the humanities has taken root (Pigliucci 2012).

One of the challenges in writing across the fields of women's studies and the biological sciences involves the question of genre. How best to narrate the idea of variation and diversity than in the very form of the book? Feminists have long been troubled by the notion that disciplinary genres of writing are necessarily rigorous. Rather, codified genres within disciplines are a product of their individual histories. Taking this to heart, I employ multiple genres to examine

the theoretical quandaries in the field in crafting a book rich in its form and function. This book embodies the varied methods and methodologies multiple disciplines offer, an interdisciplinary text that literally sits between experimental humanities and experimental sciences. I draw from the vast repertoire of method and methodologies across the natural and social sciences, humanities and arts. In addition to traditional experimental scientific methods and historical and rhetorical analyses, I also weave in autobiography, auto-ethnography, and fiction.

The personal narrative, the use of the "I," is another site of discomfort and suspicion. In the sciences, it marks subjectivity and a lack of rigor. Yet, the historical record is replete with examples (as this book amply demonstrates) where purported objective research in the sciences that assiduously cultivates a passive voice is in fact profoundly subjective and biased. In the humanities and women's studies in particular that ushered in the importance of the personal as a site of theory making, the "I" is now viewed as overused and the personal story as dangerously standing in *as* theory (Walters 1996). Yet, the personal narrative I have found is one that eases interdisciplinary conversations and best articulates what is at stake for knowledge production as well as the biographies of individual researchers. Since one of the goals of the book is to nurture new biographies, new possibilities of professional identities and disciplinary formations, I have embraced the personal narrative as an imaginative site that helps us connect questions of women in the sciences, the culture of science, and the knowledge that individual scientists produce.

Finally, I have taken to heart recent calls for a nonhuman-centric approach to STS (Haraway 2008, Kirksey and Helmreich 2010, Margulis 1998, Margulis and Sagan 2002). To this effect, I approach the nonhuman actors not as passive objects in experiments whose true natures are "revealed" through experiments, but as living agents who shape the stories that can be told. Indeed, they help co-construct scientific knowledge, although their participation—why and how they can speak, and if they can be heard—is shaped deeply by the methods used. I have worked hard to engage the nonhuman world and to listen to and learn from the multispecies voices that make up our world.

Tracking Ghosts: Hauntings from a Eugenic Past

I have to laugh. Years after this work, having traversed the breadth of academe with interdisciplinary meanderings that have taken me through the richly diverse hallways of knowledge that academia offers, after a robust scientific training, I now see hauntings. As Salman Rushdie succinctly summarizes, "Now I

know what a ghost is. Unfinished business, that's what" (Rushdie 1988: 540). I spent most of my childhood railing against the superstitious invocation of ghosts. They filled Indian folklore, mythologies, and the rich tapestry of Indian cinema. The past could never be left alone, never forgotten, the earthly life never partitioned from the netherworlds. And here, in the hallways of rational science, in the beauty of flowers, in the changing landscapes of Southern California, in the all too scientific worlds of science and scientists, I have taught myself to see ghosts. Gory, bloody, violent ghosts from our eugenic past.

"What kind of case is a case of a ghost?" asks Avery Gordon in *Ghostly Matters*.

> It is not a case of dead or missing persons *sui generis*, but of the ghost as a social figure. It is often a case of inarticulate experiences . . . of more than one story at a time . . . In the case of modernity's violence and wounds, and a case of the haunting reminder of the complex social relations in which we live . . . what can represent systematic injury and the remarkable lives made in the wake of the making of our social world. (Gordon 1997: 24–25)

How do you learn to see ghosts? And what do you see once you learn to see them? This has been my project in FSTS. Trained in evolutionary biology, I saw a field of morning glories and asked about flower color variation. I did not ask why it was the most obvious question. The landscapes in Southern California provoked me to ask questions about native and foreign species, without questioning the blurry distinctions between the native and the alien and the histories of the plants. The problem of women in the sciences elicited strategies to increasing their numbers, without any questioning of the gendered and racialized expectations of science.

Years later, I look at the same fields and see the ghostly apparitions of a eugenic past—the many mutilated, tortured, imperiled, and dead bodies, the stigmatized, contained, disciplined bodies of communities and nations of color, the poor, those deemed mentally incompetent, inferior, the many lives deemed not worth living. In tracing the genealogy of variation, all these histories came tumbling out.

Eugenics today evokes the holocaust, racial hygiene, genocide, mass sterilizations of peoples considered "inferior," the horrors of the unholy alliance of science and politics. Eugenics was without doubt an important and fundamental aspect of many key movements in the past two centuries, intimately linked to ideologies of race, nation, and sex, and also a part of several institutions such as population control, social hygiene, state hospitals, colonial governance, and the welfare state (Dikötter 1998). Yet, eugenics, it turns out, has had very different biological and political valances at different periods, embraced by an astonish-

ing number and range of scientists with diverse political persuasions. Eugenics was thus less about a clear set of scientific principles than a "modern" way to discuss social problems in scientific terms; politicians and scientists of various political persuasions appropriated eugenic discourse to promote social policy under the guise of objective and apolitical language of science and the laws of nature (Dikötter 1998). Indeed, this book is an attempt at moving from an idea of "natural selection" to a "naturecultural selection"—in understanding both the naturecultural contexts of our organic evolution as well as the evolution and politics of scientific theories and their histories.

A genealogical exploration of the idea of variation in the field of ecology and evolutionary genetics lays bare the history of eugenics, social Darwinism, and neo-Malthusianism. The question of variation in early evolutionary biology was closely intertwined with questions of undesirable, unwanted human variation—the idiots, imbeciles, paupers, feeble minded, deformed, promiscuous, epileptics, criminals, and alcoholics. The rest we know well. The history of forced institutionalization, of sterilization, population control, and the horrendous eugenic practices across much of the world. Since World War II most of evolutionary biology has clearly and unequivocally distanced itself from eugenics. But rhetorical flourishes with little historical exploration or reflection can never exorcize all the ghosts. Indeed, eugenic ideas live on. We have also seen a resurgence of biological claims of sex, gender, race, class, sexuality, nation, and ability (Fisher 2011, Paul and Spencer 1995, Bliss 2012, Roberts 2012). The ghosts live on in almost all aspects of current biological practice. Learning to see them is not just about seeing the ghosts, seeing the history, the political and cultural legacy of the field, but about laying bare the epistemological and methodological apparatuses that have framed our seeing for more than a century.

Remember, invisible things are not necessarily "not-there." Learning to write about the invisible is "about how to write about permission and prohibitions, presence and absence, about apparitions and hysterical blindness. To write stories concerning exclusions and invisibilities is to write ghost stories. To write ghost stories implies that ghosts are real, that is to say, that they produce material effects" (Gordon 1997: 18). In learning to see ghosts, scientific practice transforms into a deep-seated historical practice, where the objects and subjects of science and their histories come hurtling into focus. But it is this kind of seeing that disciplinary thinking has systematically excluded.

Drawing from Zora Neale Hurston, Avery Gordon writes: "Ghosts hate new things . . . The reason why is because ghosts are characteristically attached to the events, things, and places that produced them in the first place; by nature

they are haunting reminders of lingering trouble. Ghosts hate new things precisely because once the conditions that call them up and keep them alive have been removed, their reason for being and their power to haunt are severely restricted" (Gordon 1997: xix). Indeed, evolutionary biology has stayed within the same eugenic scripts of biological determinism and essentialist thinking, reproducing the hierarchies of sex, gender, race, class, sexuality, and nation. Reading the history of science is like playing whack-a-mole. Each time a claim of biological determinism has been dismantled, another one rises up. Each time, FSTS has pointed to the poor sample sizes, faulty logic, reductive methodologies, poor methods, or unwarranted conclusions. Yet our newspapers and scientific journals are filled with renewed claims about sex differences, racial differences, sexuality differences, and national differences. The politics of sex, gender, race, class, sexuality, and nation continue to haunt the construction of scientific knowledge.

I return to my naive conceptions of the beliefs of an apolitical and value-free institution when I first entered the hallways of science. The "culture of no culture" turns out to be entirely about culture, identity, and difference, as does scientific knowledge. What has possibly been the most humbling discovery is my recognition of the symbolic power of the preternatural. Ghosts, rather than a superstitious legacy of a past, are a haunting reminder of an ignored past. Rendering ghosts visible and learning to listen to them attentively is a lesson about the unacknowledged and unresolved injustices of history. Living with ghosts forces you to confront the past, or the dead never go away, history never sleeps, the truth can never be erased, forgotten, or foreclosed by modernity. As long as we stay embedded in the scripts of disciplinary thinking that have haunted evolutionary biology for the past two hundred years, the ghosts will continue to haunt us.