6 Feminist STS and the Sciences of the Artificial

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The past twenty years have seen an expanding engagement at the intersection of feminist scholarship and science and technology studies (STS). This corpus of research is now sufficiently rich that it invites close and more circumscribed reviews of its various areas of concentration and associated literatures. In that spirit, the aim of this chapter is to offer an integrative reflection on engagements of feminist STS with recent developments in a particular domain of science and technology, which I designate here as the sciences of the artificial.[1] Building on previous discussions relating the perspectives of feminist research to technology more broadly, the focus of this chapter is on developments at the shifting boundary of nature and artifice as it figures in relations between humans and computational machines. Central projects are those collected under the rubric of the cognitive sciences and their associated technologies, including Artificial Intelligence (AI), robotics, and software agents as well as other forms of embedded computing.[2] Central concerns are changing conceptions of the sociomaterial grounds of agency and lived experience, of bodies and persons, of resemblance and difference, and of relations across the human/machine boundary.

In framing my discussion with reference to feminist STS my aim is not to delineate the latter into a discrete subdiscipline somehow apart from science and technology studies more broadly. Not only are the interconnections—historical and conceptual—far too thick and generative to support a separation, but such territorial claims would be antithetical to the spirit of the scholarship that I have selected to review. The point of distinguishing feminist-inspired STS from the wider field of research, and the "sciences of the artificial" from technosciences more broadly, is rather to draw the boundaries of this particular chapter in a way that calls out certain focal interests and concerns. I include here work done under a range of disciplinary and methodological affiliations, most centrally feminist theory, but also the sociology of science, cultural anthropology, ethnomethodology, and information studies and design. The connecting thread for the writings that I discuss is an interest in questioning antecedents and contemporary figurings of human/technology relations through close historical, textual, and ethnographically based inquiry. The research considered here is distinguished from technology studies more broadly by a critical engagement with (1) technosciences founded on the trope of "information"; (2) artifacts that are "digital"

or computationally based, (3) a lineage involving automata or the creation of machines in (a certain) image of the human and human capacities, and (4) analysis informed by, or on my reading resonant with, feminist theorizing.

I take it that a virtue of STS is its aspiration to work across disciplines in constructing detailed and critical understandings of the sociality of science and technology, both historically and as contemporary projects. Feminist scholarship, similarly, is organized around core interests and problems rather than disciplinary canons, and comprises an open-ended and heterodox body of work.[3] The aspects of feminist STS that I trace out in this chapter define a relationship to technoscience that combines critical examination of relevant discourses with a respecification of material practices. The aim is to clear the ground in order to plant the seeds for other ways of configuring technology futures.

FEMINIST STS

Certain problematics, while not exclusive to feminist research, act as guiding questions for contemporary feminist scholars engaging with technoscience. Primary among these is the ongoing project of unsettling binary oppositions, through philosophical critique and through historical reconstruction of the practices through which particular divisions emerged as foundational to modern technoscientific definitions of the real. The latter include divisions of subject and object, human and nonhuman, nature and culture, and relatedly, same and other, us and them. Feminist scholars most directly have illuminated the politics of ordering within such divisions, particularly with respect to identifications of sex and gender. A starting observation is that in these pairings the first term typically acts as the privileged referent against which the second is defined and judged.

In constituting the real, questions of resemblance and difference and their associated politics are key. The question of difference outside of overly dichotomous and politically conservative oppositions is one that has been deeply and productively engaged, particularly within feminist and postcolonial scholarship.[4] Feminist STS joins with other recent scholarship in interrogating the conceptual and empirical grounds of the collapsing but still potent boundary between those most foundational categories of science and technology, that is, nature and culture.[5] At least since Donna Haraway's famous intervention ([1985]1991), feminist scholars embrace as well the increasingly evident inseparability of subjects and objects, "natural" bodies and "artificial" augmentations. The study of those connections includes a concern with the labors through which particular assemblages of persons and things come into being, as well as the ways in which humans or nonhumans, cut off from the specific sites and occasions that enliven them, become fetishized. In the latter process, social relations and labors are obscured, and artifacts are mystified.

Feminist research shares with poststructuralist approaches, moreover, the premise that the durable and compulsory character of categorizations and associated politics of difference are reproduced through ongoing reiterations, generated from within

everyday social action and interaction.[6] Correspondingly, the consequences of those re-enactments are intelligible only as the lived experiences of specifically situated, embodied persons. Taken as enacted rather than given, the status of resemblance and difference shifts from a foundational premise to an ongoing question—one to be answered always in the moment—of "Which differences matter, here?" (Ahmed, 1998: 4). As I discuss further below, this question takes some novel turns in the case of the politics of difference between nature and artifice, human and machine.

SCIENCES OF THE ARTIFICIAL

These concerns at the intersection of feminist scholarship and STS have immediate relevance for initiatives underway in what computer scientist, psychologist, economist, and management theorist Herbert Simon famously named (1969) "the sciences of the artificial." More specifically, the perspectives sketched above stand in challenging contrast to Simon's conception of relations of nature and artifice, along several dimensions. First, Simon's phrase was assembled within a frame that set the "artificial" in counterdistinction to the "natural" and then sought to define sciences of the former modeled on what he took to be the foundational knowledge-making practices of the latter. The work considered here, in contrast, is occupied with exploring the premise that the boundary that Simon's initiative was concerned to overcome—that between nature and culture—is itself a result of historically specific practices of materially based, imaginative artifice. Second, while Simon defined the "artificial" as made up of systems formed in adaptive relations between "inner" and "outer" environments, however defined, feminist STS joins with other modes of poststructuralist theorizing to question the implied separation, and functional reintegration, of interiors and exteriors that Simon's framework implies. Rather, the focus is on practices through which the boundary of entity and environment, affect and sociality, personal and political emerges on particular occasions, and what it effects. Moreover, while Simon's project takes "information" as foundational, it is the history and contemporary workings of that potent trope that forms the focus for the research considered here. And finally, while Simon's articulation of the sciences of the artificial took as its central subject/object the universal figure of "man," the work of feminist STS is to undo that figure and the arrangements that it serves to keep in place.

In this context the rise of information sciences and technologies is a moment that, under the banner of transformative change, simultaneously intensifies and brings into relief long-standing social arrangements and cultural assumptions. The stage is set by critical social histories like Paul Edwards's *The Closed World* (1996), Alison Adam's *Artificial Knowing: Gender and the Thinking Machine* (1998), N. Katherine Hayles's *How We Became Posthuman* (1999), and Sarah Kember's *Cyberfeminism and Artificial Life* (2003), which examine the emergence of information theory and the cognitive sciences during the latter half of the last century. These writers consider how the body and experience have been displaced by informationalism, computational reductionism, and functionalism in the sciences of the artificial (see also Bowker, 1993; Helmreich,

1998; Forsythe, 2001; Star, 1989a). Artifice here becomes complicated, as simulacra are understood less as copies of some idealized original than as evidence for the increasingly staged character of naturalized authenticity (Halberstam & Livingston, 1995: 5). The trope of informatics provides a broad and extensible connective tissue as well between the production of code as software, and the productive codes of bioengineering (Fujimura & Fortun, 1996; Franklin, 2000; Fujimura, 2005).

In the remainder of this chapter I consider a rich body of STS scholarship engaged in critical debate with initiatives under the banner of the sciences of the artificial. I turn first to the primary site of natural/cultural experimentation; namely, the project of engineering the *humanlike machine*, in the form of artificially intelligent or expert systems, robotics, and computationally based "software agents." For STS scholars the interest of this grand project, in its various forms, is less as a "science of the human" than as a powerful disclosing agent for specific cultural assumptions regarding the nature of the human and the foundations of humanness as a distinctive species property. I turn next to developments in the area of *human-machine mixings*, rendered iconic as the figure of the cyborg, and materialized most obviously in the case of various bodily augmentations. I then expand the frame from the figure of the augmented body to more extended arrangements of persons and things, which I discuss under the heading of *sociomaterial assemblages*. I close with a reflection on the preconditions and possibilities for generative critical exchange between feminist STS and these contemporary technoscience initiatives.

MIMESIS: HUMANLIKE MACHINES

The most comprehensive consideration to date of relations between feminist theory and the project of the intelligent machine is unquestionably Alison Adam's (1998) *Artificial Knowing: Gender and the Thinking Machine*. Adam, a historian of science working for the past twenty years within practical and academic computing, provides a close and extensive analysis of the gendered epistemological foundations of AI. Her argument is that AI builds its projects on deeply conservative foundations, drawn from long-standing Western philosophical assumptions regarding the nature of human intelligence. She examines the implications of this heritage by identifying assumptions evident in AI writings and artifacts, and more revealingly, alternatives notable for their absence. The alternatives are those developed, within feminist scholarship and more broadly, that emphasize the specificity of the knowing, materially embodied and socially embedded subject. The absence of that subject from AI discourses and imaginaries, she observes, contributes among other things to the invisibility of a host of requisite labors, of practical and corporeal care, essential to the progress of science. Not coincidentally, this lacuna effects an erasure, from associated accounts of technoscientific knowledge production, of work historically performed by women.[7]

Adam's analysis is enriched throughout by her careful readings of AI texts and projects, and two examples in particular serve as points of reference for her critique. The first, named "State, Operator, and Result" or Soar, was initiated by AI founding father

Allen Newell in the late 1980s. The aim of the project was to implement ideas put forward by Newell and his collaborator Herbert Simon in their 1972 book *Human Problem Solving*. Adam observes that the empirical basis for that text, proposed by Newell and Simon as a generalized "information processing psychology," comprised experiments involving unspecified subjects. While the particularities of the subjects are treated as irrelevant for Newell and Simon's theory, the former appear, on Adam's closer examination of the text, to have been all male and mostly students at Carnegie Mellon University. The tasks they were asked to complete comprised a standard set of symbolic logic, chess, and cryptarithmetic problems:

> All this leads to the strong possibility that the theory of human problem solving developed in the book, and which has strongly influenced not just the development of Soar but of symbolic AI in general, is based on the behaviour of a few, technically educated, young, male, probably middle-class, probably white, college students working on a set of rather unnatural tasks in a US university in the late 1960s and early 1970s. (Adam, 1998: 94)

The burden of proof for the irrelevance of these particulars, Adam points out, falls to those who would claim the generality of the theory. Nonetheless, despite the absence of such evidence, the results reported in the book were treated by the cognitive science research community as a successful demonstration of the proposition that all intelligent behavior is a form of problem solving, or goal-directed search through a "problem space." Soar became a basis for what Newell named in his 1990 book *Unified Theories of Cognition*, though the project's aims were subsequently qualified by Newell's students, who developed the system into a programming language and associated "cognitive architectural framework" for a range of AI applications (Adam, 1998: 95).

Adam takes as her second example the project "Cyc," the grand ten-year initiative of Douglas Lenat and colleagues funded by American industry during the 1980s and 1990s through the Microelectronics and Computer Technology Corporation (MCC) consortium. Where Newell aspired to identify a general model of cognitive processes independent of any particular domain, Lenat's aim was to design and build an encyclopedic database of propositional knowledge that could serve as a foundation for expert systems. Intended to remedy the evident "brittleness" or narrowness of the expert systems then under development, the premise of the Cyc project was that the tremendous flexibility of human cognition was due to the availability, in the brain, of an enormous repository of relevant knowledge. Neither generalized cognitive processes nor specialized knowledge bases, Lenat argued, could finesse the absence of such consensual, or "common sense," knowledge. Taking objects as both self-standing and foundational, Lenat and his colleagues characterized their project as one of "ontological engineering," the problem being to decide what kinds of objects there are in the world that need to be represented (Lenat & Guha, 1989:23). Not surprisingly the resulting menagerie of objects was both culturally specific and irremediably *ad hoc*, with new objects being introduced seemingly *ad infinitum* as the need arose.

Adam observes that the Cyc project foundered on its assumption of the generalized knower who, like the problem-solver figured in Soar, belies the contingent practices of knowledge making. The common-sense knowledge base, intended to represent "what everyone knows," implicitly modeled relevant knowledge on the canonical texts of the dictionary and encyclopedia. And charged with the task of knowing independently of any practical purposes at hand, the project's end point receded indefinitely into a future horizon well beyond the already generous ten years originally assigned it. More fundamentally, both the Soar and Cyc projects exemplify the assumption, endemic to AI projects, that the very particular domains of knowing familiar to AI practitioners comprise an adequate basis for imagining and implementing "the human." It is precisely this projection of a normative self, unaware of its own specificity, that feminist scholarship has been at pains to contest.

Along with its close reading of AI texts and projects, *Artificial Knowing* includes a commentary on specifically anthropological and sociological engagements with AI practice, focusing on my early critique (Suchman, 1987; see also 2007), and those of Diana Forsythe (1993a,b; see also 2001), Harry Collins (1990), and Stefan Helmreich (1998).[8] My own work, beginning in the 1980s, has been concerned with the question of what understandings of the human, and more particularly of human action, are realized in initiatives in the fields of artificial intelligence and robotics.[9] Immersed in studies of symbolic interactionism and ethnomethodology, I came to the question with an orientation to the primacy of communication, or interaction, to the emergence of those particular capacities that have come to define the human. This emphasis on sociality stood in strong contrast to my colleagues' fixation on the individual cognizer as the origin point for rational action. A growing engagement with anthropology and with STS expanded the grounds for my critique and underscored the value of close empirical investigations into the mundane ordering of sociomaterial practices. Initiatives in the participatory or cooperative design of information systems opened up a further space for proactive experiments, during the 1990s, in the development of an ethnographically informed and politically engaged design practice (Blomberg et al., 1996; Suchman, 2002a,b). Most recently, my frame of reference has been further expanded through the generative theorizing and innovative research practices of feminist scholarship. Within this feminist frame, the universal human cognizer is progressively displaced by attention to the specificities of knowing subjects, multiply and differentially positioned, and variously engaged in reiterative and transformative activities of collective world-making.

Diana Forsythe's studies, based on time spent in the Knowledge Systems Laboratory at Stanford University in the late 1980s and early 1990s, focus on questions of "knowledge acquisition" within the context of "knowledge engineering" and the design of so-called expert systems (Forsythe, 1993a,b; 2001). Considered a persistent and intractable "bottleneck" in the process of expert system building, knowledge acquisition references a series of primarily interview-based practices aimed at "extraction" of the knowledge presumed to be stored inside the head of an expert. As the metaphors suggest, the project of the intelligent machine from the point of view of the AI prac-

titioners studied by Forsythe is imagined in terms of process engineering, the design and management of a flow of epistemological content. The raw material of knowledge is extracted from the head of the expert (a procedure resonant with the more recent trope of "data mining"), then processed by the knowledge engineer into the refined product that is in turn transferred into the machine. The problem with this process from the point of view of AI practitioners in the 1980s and early 1990s was one of efficiency, the solution a technological one, including attempts at automation of the knowledge acquisition process itself. Forsythe's critique is framed in terms of assumptions regarding knowledge implicit in the knowledge engineering approach, including the starting premise that knowledge exists in a stable and alienable form that is in essence cognitive, available to "retrieval" and report, and applicable directly to practice. In contrast she directs attention to the forms of knowing in practice that escape expert reports and, consequently, the process of knowledge acquisition. Most importantly, Forsythe points toward the still largely unexamined issue of the politics of knowledge implied in expert systems projects. This includes most obviously the laboring bodies—of scientists as well as of the many other practitioners essential to scientific knowledge making—that remain invisible in the knowledge engineers' imaginary and associated artifacts. And it includes, somewhat less obviously, the more specific selections and translations built in to the knowledge engineering project from its inception and throughout its course.

Machinelike Actions and Others

Within the STS research community it is Collins's (1990, 1995) debate with AI that is perhaps best known. Insistently refusing to take up questions of gender, power, and the like, Collins nonetheless develops a critique of AI's premises regarding the acquisition of knowledge, drawn from the Sociology of Scientific Knowledge, that has significant resonance with feminist epistemologies.[10] Building on his groundbreaking studies of the replication of laboratory science (1985), Collins demonstrates the necessity of embodied practice—formulated in his case in terms of "tacit knowledge"—to the acquisition of scientific and technical expertise. His later work develops these ideas in relation to the question of knowledge within AI and expert systems projects, with attendant distinctions of propositional and procedural, knowing that and knowing how.[11]

As Collins points out, what he designates "machine-like actions" are as likely to be delegated to humans as to be inscribed in so-called intelligent machines. This observation invites attention to the question of just which humans historically have been the subjects/objects of this form of "mechanization." Pointing to the historical relation between automation and labor, Chasin (1995) explores identifications across women, servants, and machines in contemporary robotics.[12] Her project is to trace the relations between changes in forms of machinic (re)production (mechanical to electrical to electronic), types of labor (industrial to service), and conceptions of human-machine difference. Figured as servants, she points out, technologies reinscribe the difference between "us" and those who serve us, while eliding the difference between the latter and machines: "The servant troubles the distinction between we-human-

subjects-inventors with a lot to do (on the one hand) and them-object-things that make it easier for us (on the other)" (1995: 73).

Domestic service, doubly invisible because (1) it is reproductive and (2) it takes place in the household, is frequently provided by people—and of those predominately women—who are displaced and desperate for employment. The latter are, moreover, positioned as "others" to the dominant (typically white and affluent, at least in North America and Europe) populace. Given the undesirability of service work, the conclusion might be that the growth of the middle class will depend on the replacement of human service providers by "smart" machines. Or this is the premise, at least, promoted by those who are invested in the latter's development (see Brooks, 2002). The reality, however, is more likely to involve the continued labors of human service providers. Chasin's analysis of robotics in the context of service work makes clear that, given the nonexistence of a universal "human" identity, the performance of humanness inevitably entails marks of class, gender, ethnicity, and the like. As well as denying the "smart" machine's specific social locations, moreover, the rhetorics of its presentation as the always obliging, "labor-saving device" erases any evidence of the labor involved in its operation "from bank personnel to software programmers to the third-world workers who so often make the chips" (Chasin, 1995: 75). Yet as Ruth Schwartz Cowan (1983) and others have demonstrated with respect to domestic appliances, rather than a process of simple replacement, the delegation of new capacities to machines simultaneously generates new forms of human labor as its precondition.

Situated Robotics and "New" AI

Feminist theorists have extensively documented the subordination, if not erasure, of the body within the Western philosophical canon. In *How We Became Posthuman* (1999), Katherine Hayles traces out the inheritance of this legacy in the processes through which information "lost its body" in the emerging sciences of the artificial over the last century (1999: 2).[13] Recent developments in AI and robotics appear to reverse this trend, however, taking to heart arguments to the effect that "embodiment," rather than being coincidental, is a fundamental condition for cognition.[14] The most widely cited exception to the rule of disembodied intelligence in AI is the initiative named "situated robotics," launched by Rodney Brooks in the 1980s.[15] In her generally critical review of work in AI and robotics, Alison Adam writes that developments under the heading of "situated robotics," in particular, "demonstrate a clear recognition of the way in which embodiment informs our knowledge" (1998: 149). Sarah Kember (2003) similarly sees the project of situated robotics as providing a radical alternative to the life-as-software simulationism school of Artificial Life.[16] Central to this project, she argues, is a move from the liberal humanist ideal of a self-contained, autonomous agent to an investment in "autopoesis." The latter, as formulated most famously by Maturana and Varela (1980), shifts attention from boundaries of organism and environment as given, to the interactions that define an organism through its relations with its environment. This, according to Kember, comprises recognition of life as always embodied and situated and represents "a potent resource

for debating the increasingly symbiotic relation between humans and machines" (2003: 6). But what, exactly, does it mean to be embodied and situated in this context?

The first thing to note is that discoveries of the body in artificial intelligence and robotics inevitably locate its importance *vis-à-vis* the successful operations of mind, or at least of some form of instrumental cognition. The latter in this respect remains primary, however much mind may be formed in and through the workings of embodied action. The second consistent move is the positing of a "world" that preexists independent of the body. Just as mind remains primary to body, the world remains prior to and separate from perception and action, however much the latter may affect and be affected by it. And both body and world remain a naturalized foundation for the workings of mind. As Adam points out, the question as framed by Brooks is whether cognition, and the knowledge that it presupposes, can be modeled separately from perception and motor control (1998: 137). Brooks's answer is "no," but given the constraints of current engineering practice, Adam observes, the figure that results from his ensuing work remains "a bodied individual in a physical environment, rather than a socially situated individual" (1998: 136).

It is important to note as well that the materialization of even a bodied individual in a physical environment has proven more problematic than anticipated. In particular, it seems extraordinarily difficult to construct robotic embodiments, even of the so-called "emergent" kind, that do not rely on the associated construction of a "world" that anticipates relevant stimuli and constrains appropriate response. Just as reliance on propositional knowledge leads to a seemingly infinite regress for more traditional, symbolic AI, attempts to create artificial agents that are "embodied and embedded" seem to lead to an infinite regress of stipulations about the conditions of possibility for perception and action, bodies and environments. The inadequacies of physicalism as a model for bodies or worlds are reflected in Brooks's recent resort to some kind of yet to be determined "new stuff" as the missing ingredient for human-like machines (2002: chapter 8.)

The project of situated robotics has more recently been extended to encompass what researchers identify as "emotion" and "sociability."[17] These developments represent in part a response to earlier critiques regarding the disembodied and disembedded nature of intendedly intelligent artifacts but are cast as well in terms of AI's discovery of these as further necessary components of effective rationality. The most famous materializations of machine affect and sociability were the celebrity robots developed during the 1990s in MIT's AI Lab, Cog and Kismet. Cog, a humanoid robot "torso" incorporating a sophisticated machine vision system linked to skillfully engineered electromechanical arms and hands, is represented as a step along the road to an embodied intelligence capable of engaging in human-like interaction with both objects and human interlocutors. Cog's sister robot, Kismet, is a robot head with cartoon-like, highly suggestive three-dimensional facial features, mobilized in response to stimuli through a system of vision and audio sensors, and accompanied by inflective sound. Both robots were engineered in large measure through the labors of a former doctoral

student of Brooks, Cynthia Breazeal. Both Cog and Kismet are represented through an extensive corpus of media renderings—stories, photographs, and in Kismet's case, QuickTime videos available on the MIT website. Pictured from the "waist" up, Cog appears as freestanding if not mobile, and Kismet's Web site offers a series of recorded "interactions" between Kismet, Breazeal, and selected other humans. Like other conventional documentary productions, these representations are framed and narrated in ways that instruct the viewer in what to see. Sitting between the documentary film and the genre of the system demonstration, or "demo," the videos create a record that can be reliably repeated and reviewed in what becomes a form of eternal ethnographic present. These reenactments thereby imply that the capacities they record have an ongoing existence, that they are themselves robust and repeatable, and that like any other living creatures Cog and Kismet's agencies are not only ongoing but also continuing to develop and unfold.[18]

Robotics presents the technoscientist with the challenges of obdurate materialities of bodies in space, and Kember maintains the possibility that these challenges will effect equally profound shifts in the onto-epistemological premises not only of the artificial but also of the human sciences.[19] But despite efforts by sympathetic critics such as Adam and Kember to draw attention to the relevance of feminist theory for AI and robotics, the environments of design return researchers from the rhetorics of embodiment to the familiar practices of computer science and engineering. Brooks embraces an idea of situated action as part of his campaign against representationalism in AI, but Sengers (in press) observes that while references to the situated nature of cognition and action have become "business as usual" within AI research, researchers have for the most part failed to see the argument's consequences for their own relations to their research objects. I return to the implications of this for the possibilities of what Agre (1997) has named a "critical technical practice" below but here simply note the associated persistence of an unreconstructed form of realism in roboticists' constitution of the "situation."

SYNTHESIS: HUMAN/MACHINE MIXINGS

Haraway's subversive refiguring of the cyborg ([1985]1991, 1997) gave impetus to the appearance in the1990s of so-called "cyborg anthropology" and "cyberfeminism."[20] Both see the human/machine boundary so clearly drawn in humanist ontologies as increasingly elusive. Cyborg studies now encompass a range of sociomaterial mixings, many centered on the engineering of information technologies in increasingly intimate relation with the body (Balsamo, 1996; Kirkup et al., 2000; Wolmark, 1999). A starting premise of these studies, following Haraway (1991: 195) is that bodies are always already intimately engaged with a range of augmenting artifacts. Increasingly the project for science and technology scholars is go beyond a simple acknowledgement of natural/artificial embodiment to articulate the specific and multiple configurations of bodily prostheses and their consequences. In this context, Jain (1999) provides a restorative antidote to any simplistic embrace of the prosthetic, in consid-

ering the multiple ways in which prostheses are wounding at the same time that they are enabling. In contrast to the easy promise of bodily augmentation, the fit of bodies and artifacts is often less seamless and more painful than the trope would suggest. The point is not, however, to demonize the prosthetic where formerly it was valorized but rather to recognize the misalignments that inevitably exist within human/machine syntheses and the labors and endurances required to accommodate them (see also Viseu, 2005).

One aim of feminist research on the intersections of bodies and technologies is to explore possibilities for figuring the body as other than either a medicalized or aestheticized object (Halberstam & Livingston, 1995: 1). A first step toward such refiguring is through critical interrogation of the ways in which new imaging and body-altering technologies have been enrolled in amplifying the medical gaze and in imagining the body as gendered, and raced, in familiar ways. Feminist research on biomedical imaging technologies, for example, focuses on the rhetorical and material practices through which figures of the universal body are renewed in the context of recent "visual human" projects, uncritically translating very specific, actual bodies as "everyman/woman" (Cartwright, 1997; Prentice, 2005; Waldby, 2000). More popular appropriations of digital imaging technologies appear in the synthesis of newly gendered and racialized mixings, most notably the use of "morphing" software in the constitution of science fiction depictions of future life forms. This same technology has been put to more pedagogical purposes in the case of the hybridized "Sim Eve," incisively analyzed by Hammonds (1997) and Haraway (1997).[21] Across these cases we find technologies deployed in the reiteration of a "normal" person/body—even, in the cases that Hammonds and Haraway discuss, an idealized mixing—against which others are read as approximations, deviations, and the like. Attention to the normative and idealized invites as well consideration of the ways in which new technologies of the artificial might be put to more subversive uses. Kin to Haraway's cyborg, the "monstrous" has become a generative figure for writing against the grain of a deeper entrenchment of normative forms (Hales, 1995; Law, 1991; Lykke & Braidotti, 1996).[22] This figure links in turn to long-standing feminist concerns with (orderings of) difference.

With respect to information technologies more widely, feminist scholars have pointed out the need for a genealogy that traces and locates now widely accepted metaphors (e.g., that of "surfing" or the electronic "frontier") within their very particular cultural and historical origins.[23] The point of doing this is not simply as a matter of historical accuracy but also because the repetition of these metaphors and their associated imaginaries have social and material effects, not least in the form of systematic inclusions and exclusions built in to the narratives that they invoke. The configurations of inclusion/exclusion involved apply with equal force and material effect to those involved in technology production. As Sara Diamond concisely states, it is still the case within the so-called high tech and new media industries that "what kind of work you perform depends, in great part, on how you are configured biologically and positioned socially" (1997: 84).

A guiding interest of feminist investigations of the "virtual" is the continued place of lived experience and associated materialities in what have been too easily characterized as "disembodied" spaces. Recent research moves away from debates over whether participants in such spaces "leave the body behind," toward the sometimes strange, sometimes familiar forms that computer-mediated embodiments take. Feminist research orients, for example, to the multiplicity, and specificity, of computer-mediated sociality. Through her various studies, Nina Wakeford promotes a conception of "cyberspace" as "not a coherent global and unitary entity but a series of performances" (1997: 53). Communications technologies commonly represented as offering "narrower bandwidths" than face-to-face co-presence, Sandy Stone (1999) observes, in their use can actually afford new spaces for expanding identity play.[24] More generally, these investigations suggest a conceptualization of encounters at the interface that opens out from the boundaries of the machine narrowly construed, to the ambient environments and transformative subject/object relations that comprise the lived experience of technological practice.

SOCIOMATERIAL ASSEMBLAGES

In the closing chapter of *Cyberfeminism and Artificial Life*, Kember asks, "So how should feminists contest the material and metaphoric grounds of human and machine identities, human and machine relations?" (2003: 176). In the remainder of this chapter I offer some at least preliminary responses to that question, based in recent efforts to reconfigure agencies at the human-machine interface, both materially and metaphorically, in ways informed by feminist theorizing. The figure of the assemblage helps to keep *associations* between humans and nonhumans as our basic unit of analysis.[25] The body of work that is now available to elaborate our understanding of sociomaterial relations as assemblages is too extensive to be comprehensively reviewed, but a few indicative examples can serve as illustration.

The surgery, with its growing entanglement of virtual mediations and material embodiments, has afforded a perspicuous research site. Minimally invasive, or "keyhole," surgery, for example, as it has developed over the past few decades, has involved a series of shifts in the gaze of the surgeon and attendant practitioners from the interior of the patient's body—formerly achieved through a correspondingly large incision—to views mediated first through microscopy and now through digital cameras and large screen monitors. Aanestad (2003) focuses on the labors of nurses, traditionally a feminized occupation, responsible for setting up the complex sociotechnical environment required for the conduct of "keyhole" surgery. Her analysis follows the course of shifting interdependencies in the surgical assemblage, as changes to existing arrangements necessitate further changes in what she names the *in situ* work of "design in configuration" (2003: 2). At the same time Prentice (2005) finds that, rather than being alienated from the patient's body through these extended mediations, surgeons accustomed to performing minimally invasive surgery experience themselves as proprioceptively shifted more directly and proximally into the operative site, with the

manipulative instruments serving as fully incorporated extensions of their own acting body. As Prentice observes of these boundary transformations: "When the patient's body is distributed by technology, the surgeon's body reunites it through the circuit of his or her own body" (2005: 8; see also Goodwin, in press; Lenoir & Wei, 2002).

Myers (2005) explores the transformation of body boundaries that occurs as molecular biologists incorporate knowledge of protein structures through their engagement with physical and virtual models. Interactive molecular graphics technologies, she argues, afford crystallographers the experience of handling and manipulating otherwise intangible protein structures. The process of learning those structures involves not simply mentation but a reconfiguration of the scientist's body, as "protein modelers can be understood to 'dilate' and extend their bodies into the prosthetic technologies offered by computer graphics, and 'interiorize' the products of their body-work as embodied models of molecular structure" (in press). The result, she proposes, is a kind of "animate assemblage" of continually shifting and progressively deepening competency, enabled through the prosthetic conjoining of persons and things.

A more violent form of human-machine assemblage is evident in Schull's (2005) account of the interconnected circuitry of the gaming industry, digital gambling machine developers, machines, and gamblers in Las Vegas, Nevada. Her ethnography explores "the intimate connection between extreme states of subjective absorption in play and design elements that manipulate space and time to accelerate the extraction of money from players" (2005: 66). Values of productivity and efficiency on the part of actors in the gaming industry align with players' own desires to enter into a simultaneously intensified and extended state of congress with the machine, enabled through the progressive trimming of "dead time" from the cycles of play. As in molecular modeling, physical and digital materials are joined together to effect the resulting agencies, in this case in the form of input devices and machine feedback that minimize the motion required of players, ergonomically designed chairs that maintain the circulation of blood and the body's corresponding comfort despite the lack of movement, and computationally enabled operating systems that expand and more tightly manage the gaming possibilities. The aim of developers and players alike is that the latter should achieve "a dissociated subjective state that gamblers call the 'zone,' in which conventional spatial, bodily, monetary, and temporal parameters are suspended," as the boundary of player and machine dissolves into a new and compelling union. The point, the compulsive gambler explains, is not to win but to keep playing.

The crucial move in each of these studies is a shift from a treatment of subjects and objects as singular and separately constituted to a focus on the kinds of connections and capacities for action that particular arrangements of persons and things afford. The idea of subject/object configurations as an effect of specific practices of boundary-making and remaking is elaborated by feminist physicist Karen Barad, who proposes that stabilized entities are constructed out of specific apparatuses of sociomaterial "intra-action" (2003). While the construct of *interaction* presupposes two

entities, given in advance, that come together and engage in some kind of exchange, *intra-action* underscores the sense in which subjects and objects emerge through their encounters with each other. More specifically, Barad locates technoscientific practices as critical sites for the emergence of new subjects and objects. Taking physics as a case in point, her project is to work through long-standing divisions between the virtual and the real, while simultaneously coming to grips with the ways in which materialities, as she puts it, "kick back" in response to our intra-actions with them (1998: 112). Through her readings of Niels Bohr, Barad insists that "object" and "agencies of observation" form a nondualistic whole: it is that relational entity that comprises the objective "phenomenon" (1996: 170). Different "apparatuses of observation" enable different, always temporary, subject/object cuts that in turn enable measurement or other forms of objectification, distinction, manipulation and the like *within* the phenomenon. The relation is "ontologically primitive" (2003: 815), in other words, or prior to its components; the latter come about only through the "cut" effected through a particular apparatus of observation. Acknowledging the work of boundary making, as a necessary but at least potentially reconfigurable aspect of reality construction, suggests a form of accountability based not in control but in ongoing engagement.

SITES OF ENGAGEMENT

Among the various contemporary approaches to the study of science and technology within the social sciences, feminist research practices are marked by the joining of rigorous critique with a commitment to transformative intervention. However compelling the critique, intervention presupposes forms of engagement, both extensive and intensive, that involve their own, often contradictory positionings. In particular, the disciplines and projects that currently dominate professional sites of technology production are narrowly circumscribed, and the expected form of engagement is that of service to established agendas. Reflecting upon this dilemma in an essay titled "Ethics and Politics of Studying Up" (1999[2001]), Forsythe poses the question of how we should practice an anthropology within, and of, powerful institutions that is at once critical and respectful. Respectful critique, she argues, is particularly problematic when ours are dissenting voices, in settings where anthropological affiliations grant us marginality as much as privilege. In response to this essay, I have suggested that recent reconceptualizations of ethnographic practice, from distanced description to an engagement in multiple, partial, unfolding, and differentially powerful narratives can help recast the anthropologist's dilemma (Suchman, 1999a). This recasting involves a view of critique not as ridicule but as a questioning of basic assumptions, and of practice not as disinterested but as deeply implicated. At the same time, I would maintain that respectful critique requires the associated incorporation of critical reflection as an indigenous aspect of the professional practices in question (see Agre, 1997).

In *Cyberfeminism and Artificial Life* (2003), Kember examines the relations between two broad arenas of scholarship and technology building at the intersection of femi-

nism and the sciences of the artificial, which she identifies as cyberfeminism and ALife respectively.[26] Kember is concerned that those whom she identifies as cyberfeminists have maintained a distanced, outsider's relation to developments in ALife. Insofar as the view has remained that of the outsider, she argues, it has remained an exclusively critical one. Rather than exemplifying a generative reworking of the boundaries of nature and culture, ALife appears to the feminist critic to reinscribe the most conservative versions of biological thinking (2003: viii). In contrast, seen from within, Kember proposes that just as feminism is internally heterogeneous and contested, so are discourses of ALife. The conditions for dialogue are provided by these endogenous debates, in her view, as long as the outcome imagined is not resolution but risk—a risk that she urges cyberfeminists to take. This raises the question of whether, or to what extent, a critical exchange must—at least if it is to be an exchange—involve a reciprocity of risk. If so, is it really, or at least exclusively, feminism that has failed to take risks across these disciplinary boundaries?[27]

Haraway proposes that it is a concern with the possibilities for "materialized refiguration" that animates the interests of feminist researchers in science and technology (1997: 23). Figuration recognizes the intimate connections of available cultural imaginaries with the possibilities materialized in technologies. The contemporary technoscience projects considered here involve particular ways of figuring together, or *configuring*, humans and machines. It follows that one form of intervention is through a critical consideration of how humans and machines are figured in those practices and how they might be figured and configured differently. The most common forms of engagement are interdisciplinary initiatives aimed at reconfiguring relations of design and use (Balsamo, in press; Greenbaum & Kyng, 1991; Ooudshorn & Pinch, 2003; Lyman & Wakeford, 1999; Star, 1995b; Suchman, [1994]1999b, 2002a,b).[28] While these developments bring researchers onto politically charged and variously compromised terrain, they open as well new spaces for theoretical and political action.

My aim in this chapter has been to draw out a sense of the critical exchange emerging in feminist-inspired STS encounters with new digital technologies and the plethora of configurations that they have materialized. This exchange involves a spectrum of engagements, from questions regarding received assumptions to dialogic interventions and more directly experimental alternatives. Theoretically, this body of research explores the rewriting of old boundaries of human and nonhuman. Politically and practically, it has implications for how we conceptualize and configure practices of information technology design and use and the relations between them. I take an identifying commitment of feminist research to be a deeper appreciation of the specific relationalities of the sociomaterial world, combined with forms of constructive engagement aimed at more just distributions of symbolic and economic reward. The moves that Haraway encourages, toward recognition of the material consequences of the figural and the figural grounds of the material, and toward a different kind of positioning for the researcher/observer, mark the spirit of feminist STS. This effort engages with the broader aim of understanding science as culture,[29] as a way of shifting the frame of analysis—our own as well as that of our research subjects—from the

discovery of universal laws to the ongoing elaboration and potential transformation of culturally and historically specific practices to which we are all implicated, rather than innocently modest, witnesses.

Notes

My thanks to the editors of the *Handbook* and its reviewers, in particular Toni Robertson for her close and critical reading of early versions of this chapter.

1. Adopted from Simon, 1969. I return to a consideration of Simon's use of this phrase below. For useful overviews of feminist STS more broadly, see Creager et al., 2001; Harding, 1998; Keller, 1995, 1999; Mayberry et al., 2001; McNeil, 1987; McNeil and Franklin, 1991. For introductions and anthologies on gender and technology, see Balka & Smith, 2000; Grint & Gill, 1995; Terry & Calvert, 1997; Wajcman, 1991, 1995, 2004; and for indicative case studies, see Balsamo, 1996; Cockburn, 1988, 1991; Cockburn & Ormrod, 1993; Cowan, 1983; Martin, 1991.

2. Related areas of contemporary scholarship that are not encompassed in this chapter include artificial life, computer-mediated communication, cultural and media studies (particularly close and critical readings of science fiction and related popular cultural genre), and feminist critiques of reproductive and biotechnologies. My decision to focus the chapter more narrowly is a (regrettably) pragmatic one and a sign not of the unimportance of these areas but, on the contrary, of the impossibility of doing them justice in the space available. At the same time, I do attempt to cite some indicative points of interchange and to emphasize the interrelatedness of concerns. For critical discussions of projects in artificial life informed by feminist theory, see Adam 1998: chapter 5; Helmreich, 1998; Kember, 2003. For feminist writings in the area of computer-mediated communication and new media, see Cherny, 1996; Robertson, 2002; Star, 1995a; and on reproductive and biotechnologies, see Casper, 1998; Clarke, 1998; Davis-Floyd & Dumit, 1998; Franklin & McKinnon, 2001; Franklin & Ragone, 1998; Fujimura, 2005; Hayden, 2003; M'Charek, 2005; Strathern, 1992; Thompson, 2005.

3. I embrace here the suggestion of Ahmed et al. that "if feminism is to be/become a transformative politics, then it might need to refuse to (re)present itself as programmatic" (2000: 12).

4. For some exemplary texts, see Ahmed, 1998; Ahmed et al., 2000; Berg & Mol, 1998; Braidotti, 1994, 2002; Castañeda, 2002; Gupta & Ferguson, 1992; Law 1991; Mol, 2002; Strathern, 1999; Verran 2001.

5. See, for example, Franklin, 2003; Franklin et al., 2000; Haraway, 1991, 1997. Haraway's early writings employed the conjunctive "/" to join nature and culture together, but she subsequently erased this residual trace of dualism; see Haraway, 2000: 105.

6. For the definitive articulation of a performative approach to normativity and transgression, see Butler, 1993. See also the call of Ashmore et al. for "a rejection of a resolution of the question of relations between human and nonhuman, particularly with respect to agency, through recourse to 'essentialist ontological arguments'" (1994: 1). On the centrality of categorization practices in scientific practice and everyday action, see also Lynch, 1993; Bowker & Star, 1999.

7. This invisibility turns on the erasure of bodies, as either knowing subjects or the objects of women's labor. Historically, as Adam points out:

> Women's lives and experiences are to do with bodies, the bearing and raising of children, the looking after of bodies, the young, old and sick, as well as men's bodies in their own, and others' homes, and in the workplace. (1998: 134)

I return to the question of embodiment below, but note here Adam's point that it is this practical care of the body, in sum, that enables the "transcendence" of the mind.

8. For another early engagement, see Star 1989b.

9. Unfortunately, Adam reiterates a prevalent misreading of my argument in *Plans and Situated Actions* (1987), stating that I propose that people do not make plans but rather act in ways that are situated and contingent (Adam, 1998: 56–57). See my attempts to remedy this misunderstanding in favor of a view of planning as itself a (specific) form of situated activity (Suchman, 1993, 2007) as well as the intervention represented in Suchman and Trigg (1993) regarding AI's own situated and contingent practices. More egregiously, Adam attributes to me the position that "members of a culture have agreed, known-in-common, social conventions or behavioral norms and that these shape agreement on the appropriate relation between actions and situations" (Adam, 1998: 65). Read in context (Suchman, 1987: 63), this is instead a characterization that I offer of the position *against which* ethnomethodology is framed, proposing that rather than pregiven and stable in the way that it is assumed to be in structural functionalist sociology, "shared knowledge" is a contingent achievement of practical action and interaction. Note that this latter view has profound implications for the premises of the Cyc project as well.

10. Once again, this is not to suggest that Collins himself is engaged in feminist scholarship, but simply that his work provides some invaluable resources for others so engaged. Adam observes that, across his own writings, Collins, like the AI practitioners he critiques, presumes a universal reader-like-himself, positing things that "everyone knows" without locating that knowing subject more specifically (Adam, 1998: 65). This is consistent, she points out, with the tradition of the unmarked subject prevalent in Western moral philosophy; an implied knower who, as feminist epistemologists have argued, is only actually interchangeable with others within the confines of a quite particular and narrow membership group. Feminist epistemology, in contrast, is concerned with the specificity of the knowing subject, the '*S*' in propositional logic's '*S* knows that *p*.' "Yet," Adam observes, "asking 'Who is *S*?' is not considered a proper concern for traditional epistemologists" (1998: 77).

11. See also Dreyfus, [1979]1992.

12. The dream of machines as the new servant class comprises a translation from the robot visions of the industrial age to that of the service economy. This vision is clearly presented in innumerable invocations of the future of human-computer interactions, perhaps most notably by Brooks, 2002. For further critical discussions, see Berg, 1999; Crutzen, 2005; Gonzalez, (1995)1999; Markussen, 1995; Turkle, 1995: 45; Suchman, 2003, 2007: chapter 12.

13. See also Balsamo, 1996; Adam, 1998; Gatens, 1996; Grosz, 1994; Helmreich, 1998; Kember, 2003. For useful anthologies of writings on feminist theories of the body, see Price & Shildrick, 1999; Schiebinger, 2000.

14. For anthropological writings that made some contribution to this shift, see Suchman, 1987; Lave, 1988. For accounts from within the cognitive sciences, see also Hutchins, 1995; Agre, 1997; for overviews, see Clark, 1997, 2001, 2003; Dourish, 2001.

15. For formulations of Brooks's position written for a general reader, see Brooks, 1999, 2002. For a more extended consideration of the tropes of embodiment, sociality, and emotion in situated robotics, including an account of how a concern with the "situated" might have made its way into the MIT AI lab, see Suchman, 2007: chapter 14.

16. Kember takes as her primary exemplar roboticist Steve Grand. For a critique of Grand's latest project in situated robotics, named "Lucy the Robot Orangutan" (Grand 2003), read through the lens of Haraway's history of primatology and the "almost human," see Castañeda & Suchman, in press.

17. See, for example, Breazeal, 2002; Cassell et al., 2000; Picard, 1997. See also Castañeda, 2001; Wilson, 2002.

18. For an examination of the mystifications involved with these modes of representation, see Suchman, 2007: chapter 14.

19. Her argument here is resonant with that of Castañeda (2001).

20. See, for example, Downey & Dumit, 1997; Fischer, 1999; Hawthorne & Klein, 1999; Kember, 2003.

21. On figurings of race in online venues, see Nakamura, 2002.

22. Along with its generative connotations, the "monster," like the "cyborg," can become too easy and broad, even romanticized, a trope. Both are in need of careful analysis and specification with respect to their historical origins, their contemporary manifestations, and the range of lived experiences that they imply.

23. See, for example, Miller, 1995. Miller's focus is on the "frontier" metaphor as it invokes the need for "protection" of women and children. Who, she asks, are the absent others from whom the danger comes? The further implication, of course, is of an expansion of ownership over territories constructed as "empty" in ways that erase those "others" who have long inhabited them, albeit in different (and for those invested in the frontier), unrecognizable ways. For widely cited discussions of women's presence online, particularly in the ongoing productions, constructions, and engagements of the World Wide Web and the Internet more broadly, see Wakeford, 1997; Spender, 1996.

24. This is, of course, Sherry Turkle's position as well. See Turkle, 1995.

25. The trope of the "assemblage" has been developed within science studies to reference a bringing together of things, both material and semiotic, into configurations that are more and less durable but always contingent on their ongoing enactment as a unity. See Law, 2004: 41–42.

26. Both of these terms are defined broadly by Kember: cyberfeminism affords a general label for feminist research and scholarship concerned with information and communications technologies, artificial life or any research in artificial intelligence or robotics that, in rejecting the tenets of "good old-fashioned AI" (GOFAI), comprises what roboticist Rodney Brooks terms the "nouvelle AI" (2002: viii). This is in contrast to more circumscribed uses of the term cyberfeminism on the one hand, to reference in particular the enthusiastic hopes for networked, digital technologies; or of ALife, on the other hand, to identify the particular lines of computationalism involving the simulation of biological systems in software.

27. The risk, moreover, may not only be that of a challenge to one's deeply held beliefs. An even more dangerous possibility may be that of appropriation of one's position in the service of another, which is further entrenched, rather than reworked, in the process.

28. I have suggested ([1994]1999b, 2002a,b) that responsible design might be understood as a form of "located accountability," that would stand in contrast to existing practices of "design from nowhere." Adam (1998) unfortunately translates the latter phrase into the problem that "no one is willing to hold ultimate responsibility for the design of the system, as it is difficult to identify the designer as one single clearly identifiable individual" (1998: 79). My argument is that, insofar as no one designer does have ultimate responsibility for the design of a system or control over its effects, accountable design cannot depend on any simple idea of individual responsibility. Rather, located accountability with respect to design must mean a continuing awareness of, and engagement in, the dilemmas and debates that technological systems inevitably generate.

29. See Pickering, 1992; Franklin, 1995; Helmreich, 1998; Reid & Traweek, 2000.

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