FOUR GENEALOGIES FOR A RECOMBINANT ANTHROPOLOGY OF SCIENCE AND TECHNOLOGY

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INTRODUCTORY OVERTURE

The call of and for an Anthropology of Science and Technology requires a new generation of robust switches to translate legacy genealogies to public futures.[1] Just as we have moved from Mertonian sociologies of science (stressing the regulative ideals of organized skepticism, disinterested objectivity, universalism, and communal ownership of ideas) to analyses of what scientists actually do (the slogans of the "new sociologies of science," i.e., social studies of knowledge (SSK), and "social construction" of technology [SCOT], and of the anthropologically informed ethnographies of science and technology of the 1990s), so too we need now to formulate anthropologies of science and technology that attend to both the cultural switches of the heterogeneous communities within which sciences are cultured and technologies are peopled, and to the reflexive social institutions within which medical, environmental, informational, and other technosciences must increasingly operate.

Public futures are playing out in culturally and socially contested sites around the world where knowledges are generated and infrastructures are assembled, empowering some and disempowering others, calling for effective engagement across cultural difference. These public futures can be seen emerging in today's sciences of climate change and biodiversity built on knowledge of the Amazon, Indonesia, or the environment of circumpolar populations (Callison 2007; Lahsen 2001, 2004, 2005; Lowe 2006; Tsing 2005); in the way knowledge of the risks of

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toxic and radioactive waste is assembled from many different sciences and from the experiences at Minamata, Love Canal, Bhopal, Chernobyl, and Woburn (Brown and Mikkelson 1990; Fortun 2001; George 2001; Harr 1995; Petryna 2001; Reich 1991); in the differentiating implementation of the World Wide Web through offices in 18 countries; in harmonization conventions for clinical trials around the world contested by countries that wish to ensure their own local populations are part of those trials and not subject to standards set by other populations both for political economic and medical reasons (Kuo 2005; Petryna 2005; Petryna et al. 2006); and in molecular biomedicine and plant genetics laboratories in China peopled by postdoctoral fellows trained in the United States or the tissue engineering of palms and fruit trees in Iran on an industrial scale.

Reflexive social institutions are responses to decision-making requirements when unprecedented ethical dilemmas arise.[2] Examples include (1) health care, the conflicts between patient demands for all possible care and doctors' sense that further intervention is futile, causing harm and wasting resources (requiring hospital level ethics boards), or in the dilemmas iteratively reviewed in ethics rounds across hospitals with doctors, patient advocates, lawyers, nurses, and clergy; (2) biomedical research and policy, using scenario planning to anticipate social, legal, and ethical issues stemming from stem cell research, nuclear transfer "cloning," or xenotransplantation; (3) critical technologies, where multiple communities of expertise must be negotiated (e.g., engineers and managers in NASA technologies, visible in the space shuttle disasters); (4) environmental and ecological arenas, where toxic threats to ground water, plant life, and human health require citizen action panels with their own (limited) ability to hire independent experts to negotiate with (less limited) corporate, military or government expertise and authority (as provided in U.S. superfund legislation); and (5) computer infrastructure policy, as in legal conflicts over intellectual property (IP) and social access rights, and struggles between copyright and "copy-left" or open source in economically and legally sustainable innovation. More generally, public futures are at stake and reflexive social institutions need to be built where multiple technologies interact to create complex terrains or "ethical plateaus" for decision making. Reflexive social institutions integrate knowledge from multiple sources, often are self-organizing and learning organizations, and respond to new circumstances more easily than brittle, bureaucratic forms of agrarian empires, industrial societies, or closed system, input–output, command-and-control economies.

Reflexive social institutions are also responsive to the evolution of democratic decision making in perforce multicultural worlds. We need an anthropology of science and technology that pays detailed attention to civic epistemologies and cultures of politics, to epistemologies and presuppositions of policy formulation, making them more reflexive, inclusive, and open to airing and negotiating conflicting interests, situations, requirements and demands in ways that build legitimacy, without thereby making them unwieldy or formalistic.

As we move into worlds that are increasingly dependent on linked databases and informatics infrastructures, that require new modes of reflexive social decision making, that are accountable not just to instrumental values but also to the differential cultural sensibilities of affected and invested people in different social and cultural niches, we will need enriched anthropologies of science and technology to inform, critique, and iteratively reconstruct the emergent forms of life already forming around us. No longer can we rest on broad claims about the alienation of the market, the technicization of life, or globalization. The programming "object-oriented languages" of SSK and SCOT, and the cultural skeins and social analyses of anthropologically informed 1990s ethnographies of science and technology, have made more realistic the demand for attention to the reconstruction of public spheres, civil society, and politics in our emergent technoscientific age.

Anthropologically informed ethnographies of science and technology, in distinction to SSK and SCOT style work, began (as a first approximation) with the work of Sharon Traweek (1988), Emily Martin (1987), and Donna Haraway (1989), and in slightly different sublineages Lucy Suchman (1987) and Sheila Jasanoff (1990).[3] The gendered differentiation from the almost exclusively male and rhetorically combative SSK and SCOT tradition is not incidental, but a visible effect of anthropology's conversation in the 1980s with feminist studies, cultural studies, postcolonial studies, and media studies, and with its call to turn the jeweler's eye of ethnography on the key technoscientific institutions of the First World, and to reintegrate political economy with cultural analysis (Marcus and Fischer 1986). It is also not incidental that Traweek took on the "hard case" of high energy physics (a slogan of SSK and historians of science, not to deal with soft medical sciences until the hard basic natural sciences had been shown to be "socially constructed"); or that Donna Haraway created a reflexive project that focused on the intermingling of folk ideologies, anxieties, and practices with the "scientific" assertions of primatologists and sociobiologists. These scholars might be considered *moral pioneers* in the anthropology of science and technology, to borrow the term used by Rayna Rapp to describe women who faced critical decisions following amniocentesis tests. Like them, Traweek, Martin, and Haraway had to proceed without established guides, keenly aware of the high stakes involved, and affirming the power of multiple cultural, political, and ethical logics over and above the workings of "scientific" ones.

Since the 1980s, entry points into the anthropology of science and technology have further diversified. For simplicity of exposition, I will map four quasidistinctive genealogies of the anthropology of science and technology, which together have channeled (as in séances, involving fantasies or hyperbolic claims; as well as served as sober working reference canons or quasiresearch programs) the 1990s into the early 21st century.

CULTURAL SKEINS, EPISTEMOLOGIES, AND DEMOCRACIES TO COME (1930s and 1960s)

The "1930s" (as shorthand for the feelings of crisis in politics, economics, as well as science and morals or ethics in the period between WWI and WWII and of the Great Depression) remains a major historical horizon against which debates about science and technology measure themselves. At least three of these interconnected debates continue to have ramifying legacies and consequences: debates over technology (Heidegger vs. the Frankfurt School); debates over the demarcation, autonomy, and unity of science (Vienna Circle; J. D. Bernal vs. Michael Polanyi); and debates over phenomenology (1920s–50s) and its successors in the postwar period ("1968"): structuralism, hermeneutics, and poststructuralism as methods in the natural sciences as well as the social sciences.

From a 21st-century perspective, one can review the contending philosophers, sociologists, and anthropologists of science, technology, ethics, and morals of the 1930s—with their similarities of language, sharp animosities, Eurocentric parochialisms, and sometimes fierce cultlike followers today—as working in a fertile milieu or medium of repetition and difference, reproduction and mutation, critique through mimesis with a difference,[4] and metabolizing opponents, through which experimental, epistemic, and practical knowledge occurs. Their debates, slogans, and misrepresentations of one another constitute a kind of prehistory of STS studies, in the sense of temporally and conceptually marking a territory to be investigated, to be broken apart (analyzed), and tested (subjected to assay) by the in situ fieldwork of later generations. This era still structures deep, but often misrecognized,[5] concerns for us today. Key legacies of productive method as well as political and ethical stakes, continue to resonate in today's equally, but differently (less Eurocentric, more globally), contentious world.

Science Wars: Autonomy and Demarcation of Science: Vienna Circle, Bernal-Polanyi

Debates over the demarcation of science (William James, the Vienna Circle, the Pragmatists, and Operationalism),[6] the historicity and hermeneutics of the sciences (Ludwik Fleck), and the methods of the social sciences, especially with regard to the technicity of constitutions (Weber 1918a), the culture industry (Walter Benjamin, Theodor Adorno, and Paul Lazarsfeld),[7] and the autonomy of science versus demands to direct its development for social ends (chemist Michael Polanyi vs. crystallographer J. D. Bernal) all remain fiery synapses of contention, even if some of their contexts of articulation have changed.

Hans Jörg Rheinberger, author of a 1997 historical ethnography of the Massachusetts General Hospital laboratory in which protein synthesis was elucidated using a rat-liver experimental system, in his most recent explorations of what I am calling the prehistory of the anthropology of science and technology studies, with particular focus on "the epistemology of the concrete" in modern biology, cites Gaston Bachelard's 1928 remark that, "The history of science teaches that every great step in the direction towards demonstrating a final reality shows that this reality turns out to lead in a quite unexpected direction."[8] This is, as Rheinberger points out, one of a range of similar comments by Edmund Husserl, Ludwik Fleck, and others who attempted to demonstrate that scientific progress is neither a process of perfection, nor an approach toward teleological ends, but a continuous process of differential reproduction (Rheinberger 2006:38).[9]

Such formulations in the 1920s and 1930s intervened in the debates over whether there was a difference in principle between the natural and human sciences, between the physical and biological sciences,[10] or among the different life sciences (evolutionary biology, developmental biology, physiology, bacteriology, immunology, and genetics). Husserl tried to show in his 1936 "Question about the Origin of Geometry as Intentional-Historical Problem" that one cannot maintain the sharp distinction between epistemological–theoretical Aufklärung in the sciences and historical–narrative–explanation *Erklärung* in the human sciences.

If it was Immanuel Kant who set the agenda of thinking about democracies to come as scientific, moral, and pedagogic endeavors, it was Ludwik Fleck, a German Polish immunologist who provided in 1935 the first ethnographically grounded study of a biomedical science with his analysis of the development of the Wasserman test for syphilis, and the evolving understandings of both test and disease, as a case illustration and exemplar, both *Beispiel* and *Muster,* as Kant would say.[11] Fleck showed that there can be no epistemology without history, calling his approach a new realism of epistemology as process (scientific knowledge proceeds not through single experiments but through nonending serial ones) in which all new understanding is always already cultural as well as technical implementations of precedents repeated with a difference (Fleck 1929, 1935). It is a synthetic process that is, in principle if not always in fact, democratic and collective, if also built on trust and authority (Polanyi 1962; Shapin and Shafer 1985). In Bachelard's words again, "since knowledge is absolutely inextricable from its method or conditions of discovery, one must also characterize knowledge through its mode of discovery."[12] This is not too distant from the slogan of the Vienna Circle that scientific meaning is in the method of verification or confirmation, and that whatever is not in principle falsifiable or subject to empirical testing is "metaphysical" or scientifically meaningless (although it may be meaningful emotionally, poetically, theologically, or in other realms).[13] This is still what scientists today mean when they frequently call a question "philosophical," that is, not resolvable scientifically, however otherwise open to discussion.

Fleck's self-described quasi-Durkheimian, quasi-logical-positivist account of the development of the Wasserman test centrally argues: (1) that epistemology cannot dispense with history or culture in favor of logical reconstruction; (2) that the ambiguity black boxed by the short hand approximation of saying that an infectious agent causes a disease is known by every medical practitioner and scientist to be technically wrong because such agents do not always cause disease in healthy carriers (and hence as Emily Martin was to repeat six decades later [1994], the metaphors of immunology as warfare against pathogens are inexact and even misleading); (3) that principle actors in scientific discoveries cannot accurately tell us how the discoveries happened because their evolving knowledge is situated in what often turned out to be false assumptions and irreproducible initial experiments; (4) that communication never occurs without transduction and transformation; and (5) that truth is determined within a conversational arena that like any cultural form is more like an orchestra's coordination than like a proposition or mathematical proof.

Looking forward to an emergent genealogy, Fleck's first argument above about cultural skeins has been interestingly elaborated in the history and sociology of mathematics by Loren Graham and Jean-Michel Kantor (2007), Sha Xin Wei (2005), and a few others. Fleck's sociological arguments were followed up and elaborated by Thomas Kuhn's (1955) essay on *The Structure of Scientific Revolutions,* by the historical sociologist Steven Shapin and historian of science Simon Schaffer's study (Shapin and Shaffer [1985] of the 17th-century English Royal Society experiments with the leaky air pump, and Bruno Latour's [1988] account of the Pasteurization of France, all treated in more detail later in this article).

In the 1930s, there were struggles over "irrationalism," and rational use of science for development. Both of these struggles are perennial. While J. D. Bernal welcomed the Soviet example of the state direction of research so that funds and effort not be wasted on useless speculations (an ideology adopted by many developing nations, in which scientific funding required justification in terms of its practical contributions to development),[14] Michael Polanyi led the defense of free speculative science as a renewable source of often unexpected social returns, but justifiable as an activity of the highest order in its own right.[15] The fight over "irrationalism" was a fight led in different ways by both the Vienna Circle and the Frankfurt School against the neo-ontologists such as Martin Heidegger (see Phenomenology and Hermeneutics in the Natural and Social Sciences below), who they argued mystified the fundamentals of "reality" in profound sounding words, structured much like traditional mysticisms of illuminationism and partially hidden orders of being and reality.[16] And yet the appeal of a search for ultimate meaning or values, frequently grounded in philosophically tinged mystical language, if not in explicit existentialist theology, remains strong, and no doubt is one of the reasons for the continuing reference to Heidegger in some philosophies of technology.

The regulatory ideal of the democratic, public, and open-ended status of science has again become important (particularly since the changes in the structure of funding, and IP rights in biology and biomedicine, dating from the 1980 Bayh-Dole Act and Chakrabarty Supreme Court decision)[17]—renewing the need to develop new institutions for accountability and transparency for the scientifically educated community at large as well as for the expanding segments of the population whose lives are directly and indirectly affected by (1) the research being done or not being done for reasons of funding and proprietary control of information, and (2) the powerful potentials for hidden controls through database mining, correlation, and analysis such as populations have already experienced in areas such as credit ratings and insurance company decisions.

The 1930s, of course, provided potent cases of misdirection of science through political control (Lysenkoism in Russia, racial science in Germany), whereas today concern is more focused on economic and regulatory controls (funding, IP rights inhibiting free flow of information), and to an as yet underdeveloped interest in civic epistemologies and cultural presuppositions of those epistemologies (Jasanoff 2005). These are beginning to come to the fore in differences over regulations on biological research (e.g., genetically modified organisms and stem cell research) and harmonization debates (global vs. national clinical trials, free trade treaty requirements, WTO negotiations). The arenas today of the most public concern are in biomedicine and environmental toxicities (from toxic wastes to climate warming), and it is in these arenas that the most social experimentation is developing for patient and citizen access to and control of their own and research information (Fischer 2003:ch. 9).

Technologiestreit

The interwar Technologiestreit (or debates) about the implications of modern technology involved a struggle over the need to have sociologically and historically detailed ethnographic approaches to technologies as opposed to merely instrumental evaluations (cost-benefits of particular instruments, machine assemblies, or engineering systems), essentialized "ontologies" or mythologies, or efforts to institute nostalgically misrecognized premodern social solidarities and relations with "nature." This became inscribed as Malinowskian ethnographic anthropology versus transhistorical evolutionary anthropology; the Frankfurt School critical social theory versus Heideggerian phenomenology; U.S. cultural anthropology versus symbol and myth approaches to American Studies or generalized formulations by Lewis Mumford,[18] Jacques Ellul, or E. F. Schumacher (popular in the 1960s) that technology needed to be balanced by local and religious or humanistic values.

To formulate theses debates as merely between materialists and idealists, or between technological determinists and indeterminists,[19] fails to capture the richness of the historical horizon of the 1930s when technology was in fact, in concretely threatening ways, very much at issue. The debates about the technological in the 1930s arose in the aftermath of two industrial revolutions: that of textiles mills advancing the division of labor, the separation of work and home, the increasing productivity of de-skilled and disempowered labor, and the extraction of surplus value from this intensification; and that of steel, explosives, electricity, telegraph, and cinema that required the coordination of large scale engineering, bureaucratic, and statistical systems as the infrastructure of mass societies. The debates were also powered by a major world war in which, as Walter Benjamin memorably put it in 1928, a new social technobody was being forged:

> Masses of people, gases, electrical forces were thrown into the open countryside, high frequency sounds pierced the landscape, new constellations rose in the sky, air space and the depths of the ocean hummed with propellers. . . . During the last war's nights of destruction, the limbs of humankind were

> shaken by a feeling that looked like the thrill of the epileptic. And the revolts that followed it were the first attempt to bring the new body into their power. [1979:147]

Within anthropology, 19th-century evolutionary anthropology's "long-wave," linear progressive accounts of technology development lost creditability to Malinowskian and Radcliffe-Brownian ethnographic insistence on not tearing tools and machines out of their social and cultural (meaningful) contexts, while Martin Heidegger and many other so-called philosophers of technology continued the older tradition. In Heidegger's version, what passes for a criticism of modernity (mathematization, world-as-picture, and forcible extraction and storage of nature's energy as "standing reserves") turns out to be a long wave evolutionary sketch of transformations of world view from fifth-century Athens to 17th-century scientific revolution to 20th-century mass technologies of control of nature. Hannah Arendt pithily criticized Heidegger in her line, "Men, not Man, live on the earth and inhabit the world" (1958:7).

Anthropologists addressed the social relations of technologies in agriculture; "magic, science and religion" (or rational, pragmatic, symbolic, habitual, and transformative approaches to technology); magic and shamanism as pragmatic, if mystified, resistance to capitalism; religious legitimation of industrial relations; non-monetized exchange systems within expanding capitalist ones; religious and media technologies as reworking the sensorium and as technologies of the self; and the interaction of traditional and modern biomedical systems. They did so within alternating currents and minor languages of multiple cultural and epistemic worlds.[20] In the 1920s and 1930s these cultural and epistemic worlds took the names of other cultures (Trobriands, Azande, Nuer, Bemba, Ndembu, Navaho, Kwakiutl, Shavante, Yanomame, Kayapo, and Ilongot), or part societies (peasants, family firms and cooperatives, and workers' cultures), and class or colonial relations. The epistemologies and representations of "other cultures" was a matter of debate among anthropologists and philosophers of mind (Winch 1958, Gellner 1959, Sahlins 1976, 1995; Obeysekere 1992), as were questions they raised about explanatory schemes, rationalities, and protection of belief systems against falsification (Evans-Pritchard 1937; Fleck 1935; Malinowski 1935, 1948; later, Thomas Kuhn 1955; Mary Douglas 1966; Douglas and Wildavsky 1982; Kuhn 1955).

The contrast between Heidegger's "The Question Concerning Technology" (1954) and Adorno and Horkheimer's Dialectic of Enlightenment (1944) provides one access to the difference of their approaches to technology.[21] Both Heidegger and Adorno and Horkheimer directed attention to the difference between the multiple Aristotelian forms of causality, and how they had been reduced by the Enlightenment to the scientifically verifiable or technically efficient. However, whereas Horkheimer and Adorno analyzed this as a form of division of labor and differentiation of the sciences (from philosophy) and of professions among themselves, Heidegger directed us to turn back to the early Greeks, to *techne* as a form of *poesis* (not yet technology) that reveals "the primal: terror of existence, vulnerability to divine retribution, and to arbitrary fate"—precisely, McCormick (2002) notes, the psychological terrain, according to Adorno and Horkheimer, from which the (unfinished) Enlightenment sought to free us, and out of which fascism emerged under the transformed conditions of modern mass society. The potency of the fascist ritualization and aestheticization of mass politics to use and counter such existential fears was analyzed by the Frankfurt School, and others such as George Mosse (1975). The Frankfurt School focused attention on the new media technologies used by liberal democracies and totalitarian or authoritarian regimes alike. This is thematized in the chapter on "The Culture Industry" in the *Dialectic of Enlightenment* by Adorno and Horkheimer, and by Walter Benjamin in his essay "The Work of Art in the Mechanical Age of Reproduction" (1936) and its growing corpus of commentaries. It was a theme reiterated by Adorno in his unfinished, 1,000 page *Current of Music* (Adorno 2006; Hullot-Kentor 2006) and his other studies pursued in New York (the center of the broadcasting industry) and Los Angeles (the center of the movie industry; Jenneman 2007).

At issue were questions that remain vital: the political economy of the culture industry, the technological mediation of perception, and the consequences for subject and citizen formation. Although he got some technical details wrong, Adorno tried to analyze how, for instance, the technical medium of the radio made the production of music (live, not recorded music) transmission quite different from an audience hearing the same live music, an early instance of the idea of a reproduction without an original.

At issue in the technology debates of the 1930s were the balance between social direction or regulation on the one hand, and, on the other hand, individuation and moral responsibilities within organizational and infrastructural powers, as well the appropriate deployment of the powers of symbol systems. This became focused in the immediate postwar period in the debates between phenomenology and existentialism on the one hand, and structuralism on the other.

Phenomenology and Hermeneutics in the Natural and Social Sciences

Five transforms of phenomenology and hermeneutics complicate any simple reconstruction of the ferment of ideas, passion, and politics in the 1930s and their contemporary legacies for the anthropology of science and technology.

First in importance for science studies (but underexplored) are the relations between mathematics and phenomenology. Edmund Husserl began as a mathematician, and even after his conversion to philosophy under the influence of Franz Brentano (who influenced Freud and Heidegger as well),[22] his first major work, Logical Investigations (1900–01) involved a theory of linguistic and nonlinguistic signs, and was championed by the mathematician David Hilbert (Harman 2007:19). One feels the parallel with the debates in mathematics between the realists (Hilbert) and intuitionists (L. E. J. Brouwer). Husserl, somewhat like Ernst Cassirer (see Fischer 2007), viewed intentions as objectifying acts, including emotive intentions such as wishes, fears, confusion, and anger. Intentional objects are never fully present; there is always more to them than immediately is visible or evident. Therefore, Husserl argued, one should attempt to "bracket" the world of appearances to get to the underlying reality. This is a realist endeavor, rather than a search for a mystical religious insight as it became for Heidegger.[23]

A second key transform of phenomenology involved the search in Protestant theology for a philosophical formulation of religious experience as a response to the Kantian threat of reducing God to merely a postulate or regulative ideal of ethical life (Moyn 2005:123). Although this might seem to be a lesser transform for science and technology studies, it is in fact a key genealogy for Heidegger's "philosophy" of technology, and for the development of that line of philosophical thinking about intersubjectivity ("the other," alterity) that seems to studiously avoid the parallel sociological development of intersubjectivity (Dilthey, G. H. Mead, Max Weber, Emile Durkheim, Alfred Schutz). Moyn seems quite correct to locate its power of attraction in a theological need to respond to Kant as well as to the anxieties and loss of meaning at the end of the 19th century, and again in the wake of WWI in Germany (repeated to some extent in the immediate post–WWII period in France with the end of the occupation and collapse of Vichy France, as outlined by Leonard 2005). This is the genealogy of Kierkegaard and Schliermacher, Rudolf Otto, Karl Barth, Franz Rosenzweig, Martin Buber, and, after 1933, Emmanuel Levinas. Barth and Otto coined the terminology of the *Other* (viz. Otto's mysterium tremendum), and *alterity* or the *totally other* (Moyn 2005:ch. 4). The study of religious subjectivity initiated by Wilhelm Wundt and William James seemed to give these theological formulations empirical and theoretical support (Moyn 2005:123).

It is in this context that one might understand the otherwise strange claim that Heidegger "secularized" Christian theology as he moved from rejection of dogmatic Catholicism to radical Protestantism to a nationalistic religiosity rooted in Teutonic and forest myth and in Volk and Heimat (building on Hegel's picture of the Greeks as explicable wholly in terms of their autochthonous development, of the Geist der Heimatlichkeit, in opposition to Schelling's exploration of Egyptian or Eastern cultural roots [Leonard 2005:149]).[24]

A third key transform is the relationship between phenomenology, hermeneutics, intersubjectivity, and time. The tripartite relationship between present, past, and future, and its relationship to intersubjectivity and social action (intentional action as opposed to mere acts), was a core issue for thinking about the human sciences. Wilhelm Dilthey elaborated a compromise between the presumptive objectivity of describing objects (leaving quantum mechanics aside) in the natural sciences and the problem that descriptions of human action might affect the actions that the described humans take if they know about the description. The compromise was to recognize in public language and interaction a mode of negotiated intersubjectivity that can be objectively described. (John Dewey would argue something similar in his schema of movement from viewing social action as merely self-awareness, to treating social objects as Newtonian interactions, to fully communicative transactions. And, of course, George Herbert Mead is often seen as the Pragmatist philosopher of the socially formed "self.")

This notion of intersubjectivity partially sidestepped the theological focus on prereflective, preconceptual knowledge, although this would return via bodily, emotional signaling and the play of the unconscious (transform four). This intersubjectivity could encompass the agnosticism of not actually knowing what is inside the heads of particular actors through models of patterned interactions (what Max Weber and Alfred Schutz called "as if" ideal types, and Karl Mannheim unpacked in his sociology of knowledge [1922, 1936]), the linguistics of describing the codes and pragmatics of communication, the sociolinguistics of recognizing that more is communicated than the actors themselves realize at the time, and the internal dialogues and heteroglossia of thought associated with Mikhail Bakhtin. Above all, perhaps, intersubjectivity could accommodate the notion of interpretive hermeneutics that all messages undergo, and that in poststructuralist hands (Paul de Man and Jacques Derrida) would track alternative meanings carried in the ambiguities, tropes, and buried histories of modes of speaking, and that were, in some sense, traces of absences, socially and culturally, as well as logically, prior to the presence of speech acts and experiential moments. But from an anthropological and sociological point of view, as Arendt also argued, much of the philosophical literature on phenomenology had an unsatisfactory view of intersubjectivity, barely ever able to get out of a solipsistic transcendental ego (Dewey's stage of self-awareness).[25]

A fourth transform of phenomenology became the physiological, psychiatric, and perceptual phenomenology of Merleau-Ponty, particularly in his turn to Husserl's late work, *The Crisis of the European Sciences* (1936), and the temporality of lifeworlds. Merleau-Ponty's notions of "reversible flesh," of the ways in which we feel ourselves, and how we perceive through the body, proved important for the anthropology of mental health, psychiatry, and culture (Desjarlais 1992; Good 1994), as did, to a lesser extent, the phenomenology of time explored by Henri Bergson. A cross-tie with the second transform above is the existentialist phenomenologists' focus on nausea and shame as moments when riveting to the body is inescapable, and one desperately seeks for evasions that are "otherwise than Being." It seems dubious that such "bondage" to the body conflicts in any way with the development of a responsible autonomous political self, said metaphorically to be phantasmically liberated from such bondage (the source of illusions of having a sovereign view from nowhere), and indeed Jean-Paul Sartre would insist that the ego is a complex structure of aporias that functions as a site or "moment of responsibility" (Rajan 2002:58).

A fifth important transform is thus the relationship between phenomenology and freedom, of politics in public forums as the arena without which citizens and societies cannot achieve their potentials for freedom and justice. Hannah Arendt's (1958) notion of the "human condition in its plurality" is a important critique here of the solipsism of her teacher, Heidegger, and is today returning as a touchstone in thinking about how freedom is the result of agons of politics, of putting differences in play against one another, to generate a future in which all have some ownership.[26] Arendt died before the contemporary technoscientific and communication transformations, but the principles she invokes remain critical, especially in the face of seemingly overwhelming technological systems, analogous to the seemingly overwhelming political systems she analyzed. Even at the worst, individuals can band together in their differences "to people" technologies with the face and call of the other. Jean-Paul Sartre attempted to fuse a Marxist notion of the structural forces of history with an existentialist and politically engagé voluntarism (Sartre 1960). It was against the excessive voluntarism and hopes to direct historical change, stemming perhaps from the relief of having survived WWII, that Lévi-Strauss and structuralism intervened.

Structuralism

There are two connected historical moments of structuralism important for subsequent anthropologies of science and technology: the structuralism that emerges from geology, Marxism, and linguistics, and that was a general scientific language across disciplines in the early 20th century; and the structuralism of Lévi-Strauss, Lacan, Althusser, the early Bourdieu, the early Foucault, and others in the 1960s. Like the "functionalism" of the 1930s and 1940s associated with Malinowski and Radcliffe-Brown, "structuralism" is often spoken of dismissively by those who, in a kind of figure-ground gestalt switch, attempt to define new pathways against its background necessary to their own work (incl. the later Foucault and the later Bourdieu).

For the anthropology of science, the key double historical reference point in the structuralist moments have been (apart from the all-important understanding of structural linguistics as a defining method) the names of Thomas Kuhn and his 1930s predecessor, Ludwik Fleck. Kuhn took the U.S. academy by storm in the 1960s at the same time as the reception of (in their different ways) Noam Chomsky's generative grammar, and Lévi-Strauss's structuralist studies of kinship and mythology. Kuhn was notationally important for science studies because he took on the "hard" sciences (physics or astronomy), a move that was important before science studies felt confident enough to return to the "soft" sciences (biology or medicine) that Fleck had pioneered, and that Kuhn took as his inspiration. As the life sciences began to replace physics as the lead sciences of the day in the 1980s, Fleck's stock began to rise again.

Two things are important about structuralism as a set of methods for the anthropology of science. First, there is the important relationship of structuralism to mathematics: Lévi-Strauss and set theory, and Lacan and topology (first of surfaces, later of knots). This is not only metaphor: Lévi-Strauss and Lacan were in a reading group with the mathematician George Guilbaud and the linguist Emile Benveniste (Ragland and Milovanovic 2004:xx), and Lévi-Strauss's the *Elementary Forms of Kinship* was worked out in collaboration with the mathematician Andre Weyl (Rabaté, 2003:38).

Second is the much more general and now widely accepted notion, disseminated by structural linguistics (Saussure, Bloomfield, and Jakobson) and semiology (C. S. Pierce and Thomas Sebeok), that significance is created by structured sets of relationships.[27] As Saussure in 1916 famously put it, meaning resides in the system of differences. "Pill" and "bill" are phonemically different and meaningful thanks to a single binary distinction between a voiced and unvoiced labial puff of air. Linguistic meaning resides in such systematic binary differences. In a somewhat similar conceptual insight, equally powerful if practically more limited, Chomsky's famous Syntactic Structures (1957), popularized the idea that from a small set of grammatical rules one could generate the infinite number of grammatically correct utterances of a language (and, perhaps, of language in general).

This notion of generativity, the earlier notions of underlying phonemic patterns (Roman Jakobson) and systems of difference (Saussure), and the later systematization of sociolinguistic rules of pragmatics and metapragmatics (ways that situational social relations are built into linguistic markers) provide the Lévi-Straussian distinction between deep and surface structures, and the Chomskian distinction between competence and performance. Speakers of a language invariably can correct the mistakes that a language learner makes (and this provides the systematic means of elicitation for field linguists in working out grammars and semantics), but they are themselves often unaware of, and unable to specify, the systematic rules of production. Similarly, class-linked linguistic styles (pragmatics and metapragmatics) often cause confusion or misrecognition across classes because what is intended as signaling trust, intimacy, or commonality in one system marks difference from another. Those who are able to operate across two or more systems (and we all do, to some extent) are thus said to engage in "code switching." At the phonological level such code switching across languages frequently leaves traces of an "accent."

Thomas Kuhn's notion of knowledge paradigms thus fell on fertile ground and was rapidly taken up both as a way to study the competition of different scientific research programs in terms of their internal conceptual coherence and resistance to falsification, and also as a way to integrate the understanding "that political, social, and intellectual and scientific revolutions have to be discussed in a common context."[28] Over the course of the 1980s and 1990s, Peter Galison (1997) would break apart Kuhn's overly unified gestalt or paradigm approach for physics by stressing: (1) the differential changes among theory, instruments, and practice (they do not move in lockstep); (2) the necessary pidgin or creolized languages of trading zones among paradigms of different disciplines involved in the interdisciplinary work of most contemporary sciences; and (3) the inputs of perspectives, instrument traditions, and practices from outside a given scientific field proper (as in the relationship between Victorian interests in environmental turbulence and the development of cloud and bubble chambers; or the relationship between electronics and detectors in particle accelerators). Moreover, in this same period Fleck's arguments about the historical nature of epistemology would again come to the fore (see below). Both moves facilitated a rapprochement and new engagement between historians and anthropologists of science and technology.

Poststructuralism ("1968")

For science and technology studies, poststructuralism has provided analytic strategies for dissecting and reevaluating the discursive and epistemic structures of various sciences and technologies, as well as their ethical and political entanglements, including the magic pad–like historical complicities and displacements of subjectivities, desires, joys, and jouissance. Poststructuralism arrived in the United States along with structuralism in a 1966 conference on criticism and the sciences of man at the Johns Hopkins University (Macksey and Donato 1970). The term *poststructuralism* is an Anglo-American invention: the French simply used *structuralism* (Rajan 2002:34). In France poststructuralism, or the period around 1968, had to do with a broad reworking of structuralist, hermeneutical, and existentialist approaches of the immediate post–WWII period, meaning in part a reworking of the dialectical themes of machinic systematicity associated with language (metaphorized as the "inhuman" or "anti-humanism") and the "indicativeness," referentiality, or metapragmatics of all that is beyond, marginalized, or on the other side of the signifier (what Derrida for a time called the "margins" of philosophy when referring to Algeria, Vietnam, or the student rebellion of 1968). These debates carried political inflections in which (post)structuralist rereadings of "Die Griechen" (German interpretations of Antigone, Oedipus, and Socrates) provided palimpsests for rethinking the relations between politics, subjectivity, and ethics (Leonard 2005). The issues of the 1930s were revisited with an accent on emergent new technologies of the postwar period.

Jacques Derrida's work, in particular, pervasively evoked and drew attention to programming, telemedia, and molecular biology, with some of his work being explicitly read in these terms (Fischer 2001; Johnson 1993; Rheinberger 1997; Ulmer 1985, 1989, 1994). Jean-Francois Lyotard similarly speculated on the effects of computers in *The Postmodern Condition of Knowledge* (1979) and on visual modes of communication. Gilles Deleuze created concepts and philosophies on time images and moving images in cinema, on alternatives to genealogical and typological reasoning in various fields, and on the makeshift assemblages of the technological and conceptual rather than their "totalizing" systematicities (1980).[29]

These and other works have provided productive intertexts for a number of science and technology scholars, particularly those in literary and cultural studies, but also for those working directly in the history of technology, science, or the technosciences (Kittler 1985, 1986; Rheinberger 1997, 2006; Ronell 1989, 2005).

More generally, Derrida prepares the ground for genealogy in helpful preanthropology of science fashion. He argues that "ethnology [Lévi-Strauss's structuralist challenge] could have been born as a science only at the moment when a decentering had come about: at the moment when European culture—and in consequence, the history of metaphysics and its concepts—had been dislocated . . . and forced to stop considering itself as the culture of reference." Moreover, he continues, "this moment is not first and foremost a moment of philosophical or scientific discourse. It is also a moment which is political, economic, technical, and so forth" (1976:283). At issue was a shift toward a world of informatic assemblages of codes and flows, in which the globe is a space of differential generation.

* * *

In sum, the emergence of the second genealogy of science studies (SSK, SCOT, and ANT) in the 1980s was partly in reaction to these debates of the 1930s (and 1960s). Polemically directed against a mischaracterization of the philosophy of science of the Vienna Circle and of Karl Popper as being insufficiently sociological, it also attempted a soft recovery of J. D. Bernal's sociology (after whom one of the prizes of the European Society for the Social Studies of Sciences is named), but neither Bernal's activism, nor his Marxism.

II PROGRAMMING OBJECT-ORIENTED LANGUAGES: SSK, SCOT, ANT (1980s)

In computer programming, object-oriented languages allow the programmer to drag and drop convenient objects that are already pretranslated into machine language and thus ease the programming. It is a kind of black boxing, but may be more productively thought of as a creation of concepts or vocabulary that others can use without having to fully rederive and reargue their utility, meaning, and justification. The utility of the metaphor is to suggest that some of the arguments in this style of STS take on a type of programming format, not unlike the way in which scientific experimental systems, once stabilized, become tools rather than discovery systems (see the Rheinberger passage in the text box, and passim, in "Culture and Cultural Analysis as Experimental Systems" [Fischer 2007]).

Like technoscientific systems as theorized by Rheinberger (1997), the object-oriented languages in this style of STS are doubled entities, simultaneously tool or protocol that reliably reproduces, and generator of excess, surprise, and "the unprecedented." Defenders of scientific reductionism and technical terminology (*jargon, short-hand labels, heuristics, black boxing,* etc.) correctly adduce their efficiency for cumulative building of experimental and theoretical scientific work, and as well-defined communication tools. This is the protocol and tool side: take *x*, add *y*, modify by *z*; find a farmer's field, add a bacteriological laboratory as an obligatory point of passage, produce a reversal of power ratio between fieldworker and lab technician, add carefully staged public demonstrations, produce a vanguard scientific expertise over a (hygienics) social movement.[30] At the same time, the messy surplus of surprises, inassimilable information, interesting but apparently irrelevant anomalies, and similar kinds of "noise" are not only set aside, but over time also become buried and forgotten. Yet these surpluses generated by unstabilized testing often, when rediscovered in other contexts or frames of thought, prove to be valuable new resources. One needs both tool and surplus in dialectical tension or double bind: tools and protocols for reproducibility and reliability, and surplus-generating experimental systems for new effects and questions. Although the object-oriented languages of this genealogy of STS have indeed been powerful tools, I suggest that this puritan (disciplining, Apollonian, pure reason) protocol side needs some loosening in favor of the gay (Nietzschian, Diyonesian, excess producing) experimental side.

CONTRIBUTIONS OF THE SSK, SCOT AND ANT GENEALOGY

The so-called new sociology of science;[31] SSK; SCOT; and actor network theory (ANT)–style science, technology, and society (STS) constructively wielded a series of sound bites, slogans, and magical words. For anthropologists, the slogan of "social constructivism" may sound naive and blunt, a belated rediscovery of long practiced anthropological social and cultural analysis.[32] Granted, these often treated the natural sciences and technological systems marginally at best, but medical anthropologists in particular have expressed irritation that these styles of STS suddenly became prestigious while much of their investigative technologies were long practiced by medical anthropology.

Still, the contribution of these styles of STS to anthropologies of science and technology has been profound, particularly in forging the study of "epistemic objects" as experimentally produced through testing, and turning unstable experimental systems in turn into at least temporarily stabilized tools. It is a shift from viewing scientific objects and cultural forms as things to be discovered, to recognizing that the process of "discovery" is increasingly one of active production, of reconfiguring our worlds into new formations. This is never done by individuals alone but always as socially organized productions, in which the articulation of the "organization" is more important than the word *social*. The tools forged by science studies not only help unpack central infrastructures and institutions of our contemporary societies, but they also help us in other arenas of changing cultural identities, categories, objects, or forms to find vocabularies and approaches that are less vague than "hybrids," "cosmopolitanisms," "multiculturalisms," "glocals," or "hegemonies versus resistances." This is in part the challenge of the recombination of approaches for an anthropology of the technoscientific worlds of the 21st century.

Remetaphorizing this STS style or mode of focusing attention in terms of a genealogy of tools and methods foregrounds its generative capacities, its ability to produce "healthy" analysis as well as predispositions to certain "illnesses" (in Nietzsche's terms). Perhaps the most distinctive contributions of this style of STS to the anthropology of science and technology are (1) focused attention on the internal workings of science and technology from an ethnographic and sociological point of view (in contrast to reconstructive idealist and idealizing accounts of philosophy of science and intellectual history); (2) a vocabulary of terms and methodological obligations; including (3) the ethnographic study of laboratories and scientific controversies; and (4) the production of scientific or epistemic objects such as model organisms and experimental systems.

SSK, SHOT, and ANT succeeded in doing what in Bruno Latour's terms might be called public recruitment, or in Gilles Deleuze's terms the forging of an assemblage (relying on ideas that the basic utterances of language are "order-words" or slogans, and that language is machinic and enunciative, coordinating relations among literal social bodies, and thus constituting a kind of material politics; Fleck described "magic words" as performing similarly).[33] SSK, SHOT, and ANT's publicity success made the "science wars" of the 1990s possible, both for good (the Hollywood slogan "all publicity is good") and for bad (the inability to have productive conversations with some scientists who misunderstand the social analysis as a claim that there is no resistance from "the real"). In this light the primary contribution of this genealogy of science studies has been the production of vocabulary and methodological obligations including the injunctions to always pay attention to: the triad of social, material, and literary technologies (Shapin and Shafer 1985; "literary" here meaning, and restricted to, the actual writing of protocols so people not present can in principle reproduce the experiments or mentally become "virtual witnesses"); the difficulties of transferring laboratory skills and tacit knowledge of new experimental protocols (Collins 1974; Polanyi 1966); the micropractices and semantic discriminations that ethnomethodological observation shows as permeating scientific practice and thought (Lynch 1993; viz. Garfinkle 1967); the modes of drawing and representation (Lynch and Woolgar 1988); the points of obligatory passage, centers of calculation, asymmetric and reversible ratios of power and legitimacy (Latour 1988); the disjunctive histories or intercalations among the instruments, theories, and practices of a field (Galison 1997; Pickering 1995); the procedural and organizational differences among the experimental sciences (Galison and Stump 1996; Knorr-Cetina 1999); and the controversies that open and close black boxes, the networks of human and nonhuman actants that redefine agency, and the enrollment necessary for the success of projects over time (Latour 1993).

Other injunctions are of more limited value for particular purposes: so-called methodological symmetries of accounting for failures as well as success stories, or for dealing with nonhuman actants the same way as human actors. These injunctions can be defended: the first as a reminder that the openness of a field of action not be recounted retrospectively as if the outcome were obvious or preordained; the second as a reminder that parasites, disease vectors, technological systems, and assemblages can be powerful causal factors in human affairs. But their generality is limited, and in the case of ANT and granting nonhuman actors their due, the locus of responsibility can easily be discounted. (Institutional settings for ethical decision making are themselves increasingly important objects of study for anthropologies of science and technology, as they have long been for medical anthropology, development anthropology, human rights studies, and the anthropology of other institutions of public policy, regulation, and political cultures.)

Allied vocabulary and methodological obligations from anthropologists and medical and social historians who interacted with SSK, ANT, and SHOT communities have also taught us the necessity of attention to differential pedagogies, mentoring styles, and patronage networks (Traweek 1988; Warwick 2003); gentlemanly science in the 17th-century Royal Society (Shapin and Shaffer 1985) obeyed different protocols than earlier courtier science practiced by Galileo (Biagioli 1993) or later public demonstration science practiced by Pasteur (Latour 1988; see Geison 1995). Anthropologists have directed attention to circuits of knowledge dissemination and differential practical responses to technologies (Dumit 2005; Martin 1994; Traweek 1988), although some historians have adapted anthropological notions of pigeon languages and trading zones between disciplines and subdisciplines (Galison 1997).

An important project has been the delineation of different kinds of experimental systems (Cambrosio and Keating 1995; Kohler 1994; Rheinberger 1997), transitional objects and alternative styles of learning (Turkle 1995), and differences among field sciences, laboratory sciences, and simulation sciences. Cyborg anthropology (Haraway 1985; Downey and Dumit 1997) produced efforts to think through how mechanical-organic objects change cultural networks of meaning and social organizations, and how assemblages of humans and nonhuman actants create new modes of agency. Anthropologists have directed attention to how scientific visualizations are manipulated, interpreted, and circulate (Dumit 2004, how clinical trial data are manipulated through tactical "ethical variability" (Petryna 2005), how advocacy works in arenas of limited knowledge (Brown and Mikkelson 1990; Fortun 2001; Reich 1991), and how enunciatory communities thicken and contest the more instrumentalized or singularized notions of stakeholders and interests (Fortun 2001). The differentiation of different kinds of science has helped clarify presupposed social requirements or exclusions: the debate over statistically normal accidents and where in different social structures problems are likely to arise (Perrow 1999) has focused attention also on the differences between normal science working within stabilized paradigms (Kuhn 1955), consultancy science (working with well-defined questions and given information), regulatory or postnormal science (where consequential health or environmental decisions must be made in the absence of good data or well-formed questions; Funtowicz and Ravetz 1992). These latter constraints differ considerably in different countries because of differing cultural presuppositions or civic epistemologies (Jasanoff 2005), which in turn create different boundary objects, and coproduce regimes of knowledge and power.

Limitations of the SKK, SCOT, and ANT Genealogy

Although SSK, SHOT, and ANT have helped put "science studies" on the intellectual map of disciplines, provided essential object-oriented programming languages, and have produced lab studies, studies of controversies, and studies of the development of particular technologies (from bicycles to high energy particle accelerators and intelligent transportation systems), the polemical edge of the field has been directed at correcting one particular strand of philosophies of science: a particularly flat, and even polemically mischaracterized, reading of the Vienna Circle "logical positivists" (excluding their pragmatist and operationalist side), and of British analytic philosophy. Except for Latour's claim to be an acolyte of the science and humanist polymath Michel Serres, the SSK–SCOT style of STS has displayed little interest in the so-called Continental traditions of philosophical accounts of science, particularly those of the phenomenological, psychoanalytic, and structuralist or poststructuralist traditions.[34]

There are several key problems in the SSK, SCOT, ANT approaches: first, few practicing scientists take traditional analytic philosophies of science seriously, or do so only as idealized accounts in public explanations for lay people, often to counter claims that ultimate meaning must reside in religion, opinion, or particular (unrepresentative) everyday experiences. Nobel Laureate and physicist Steven Weinberg is a case in point: although he writes periodic idealist accounts of science for the *New York Review of Books* (e.g., Weinberg 2001), when pressed at the 1994 Cambridge, Massachusetts, meeting of the right wing National Association of Scholars to polemicize against science studies accounts, he noted that there is no single scientific method, that one needs to look at what scientists actually do, and that science studies was hardly an enemy—the real enemy of scientists were those with the money and votes in Congress to kill scientific funding for particle colliders or school boards that impose creationism (or nowadays "intelligent design") in science classes as if they constituted falsifiable theories.[35]

Second, the seeming effort to tell scientists that science studies might teach them how to do, or to interpret, their own science better tends to create barriers rather than elicit the shared wonder and pleasure in the serendipity, competitions, passions, even irrationalities, that are part of science and technological projects, and about which scientists delightedly talk in private. These aspects have tended to be overlooked or devalued by this tradition in STS, and instead have often been best, if partially and unsystematically, captured in novels (e.g., the novels of Richard Powers, the early John Banville, Carl Djerassi, Rebecca Goldstein, and Allegra Goodman, among others) and in drama (e.g., *Arcadia* by Tom Stoppard, *Copenhagen* by Michael Frayn, *Oxygen* by chemists Carl Djerassi and Roald Hoffmann, *Proof* by David Auburn, *Small Infinities* by Alan Brody, *On Ego* by Mick Gordon and neuroscientist Paul Broks, and at least three plays about Ramanujan by Vijay Padaki, Ira Hauptman, and David Freeman).

This points to a third set of ills: the exclusions of interest in imaginaries and the literary dimensions of science (except in the restricted sense of the literary technologies of writing protocols so that experiments can be witnessed at a distance or virtually and can be replicated) and the devaluation of the psychological or affective dimensions of science. As a result such approaches have often provoked an aggressive hyperdefensiveness in some scientists, expressed in insistences of objectivity and foundationalism beyond probable cause or plausible belief (e.g., Gross and Leavitt 1984). Such over defensiveness may sometimes be associated with an always uncertain funding environment, or with fear that airing the uncertainties, the constructiveness of experimentalism, the competitions between research groups and paradigms, and other social and psychological dynamics might put at risk the "forward-looking" statements, claims, and hype that are used to sell their projects.

A more receptive anthropological attitude that establishes a venue and audience for scientists to assist in unpacking the complex dynamics of the central scientific and technological structures of our society (which are otherwise increasingly exposed and contested only in the short-attention span and often distortingly repetitive public media) may prove to be better than a predominantly corrective and oppositional science studies style.[36]

A fourth set of shortcomings of the SSK, SCOT, and ANT approaches is the attenuation of interest in larger sociopolitical institutions of the very sort that Robert Merton, Max Weber, and others in the 1930s genealogies explored, and that these "new sociology" approaches wished temporarily to get away from (with the important exceptions of Shapin and Shafer 1985, and Latour 1988). This at a time when the very production of science, particularly in biology but also in the information sciences, is inextricably entangled with market and regulatory forces, patent law and promissory investments, as big science and big technology have been since WWII and the Manhattan Project, the founding of the National Science Foundation and the start of the space program, through the Superfund Legislation of the 1970s and beyond. On the political side, the charges against the administration of George W. Bush of falsely manipulating scientific data for political ends is a public sphere issue that has mobilized scientists and others (Shulman 2006); and on the market side, the role of protection of forward-looking statements to investors, secrecy about proprietary rights, the role of media marketing to consumer groups for drugs and medical therapies, and enforcement of WTO rules, have made the ideals of an autonomous republic of science ever more in need of vigorous probing and testing of validity claims. The so-called science wars of the 1990s, by contrast, had other, less momentous, dynamics (Fischer 2003:5–6). Many of these issues become even more obvious from within the context of postcolonial power relations.

The fifth set of problems with SSK, SCOT, and ANT type approaches is laid out most clearly by Michel Callon and Latour, the authors of ANT, themselves. They had misleadingly called it "Actor Network Theory," insisting on enrollment, nonhuman and human assemblages, agency for objects and things, and coproduction of scientific and political authority, as if they were revising sociological role theory to include technological objects. However, as Latour explained in "The Trouble with Actor Network Theory" (1996), the emphasis really should be on the nodes as metaphysical Leibnitzian monads (back to the 17th century), nodes that have "as many dimensions as they have connection." This is a notion of network derived from 18th-century Dennis Diderot's *réseau,* in opposition to René Descartes's dualism of matter and spirit; in sum, it is a notion that really has much in common with

Deleuze and Guattari's rhizome and with chaos and complexity theory. It is, Latour suggests, really a bottom up theory of "material resistance," perhaps like Michel Foucault's microcapillaries of power: "Strength does not come from concentration, purity, and unity, but from dissemination, heterogeneity, and the careful plaiting of weak ties."[37] This reinterpretation of actor networks as cultural skeins opens up Latour's work into his more recent fascination with making things public with matters of fact being really matters of concern, and (back to the 1930s) with John Dewey's (1927) notion of the public as "states of affairs," as the nontransparent, unintended, unwanted, invisible consequences of our collective actions, and, thus, precisely not the superior knowledge of the authorities but their blindness (Latour 2001d, 2004, 2005a).

In these moves, Latour reveals his anthropologist's instincts and provides a transition toward more anthropologically informed ethnographies of science and technology, and toward the kinds of social theory analyses pioneered in the 1930s and 1960s. In this, he rejoins Donna Haraway's insistence that biology is civics; Ulrich Beck's notion of risk society and reflexive institutions of second order modernization; Sheila Jasanoff's comparative studies of regulatory sciences, stressing different civic epistemologies and political cultures, which she analogizes to multilocal or multisited ethnographies (Jasanoff 2005; Marcus and Fischer 1986, 1999); Funtowicz and Ravetz's (1992) policy-relevant, nonconsultancy, sciences; Gibbons and colleagues (1994) "mode two knowledges"; Perrow's (1999) "normal accidents"; Kim Fortun's (2001) "enunciatory communities"; and Fischer's (2003) "emergent forms of life," "deep play," and "ethical plateaus."

Latour acknowledges Ulrich Beck's notion of risk society and reflexive institutions of second-order modernization, saying that "Dewey invented reflexive modernization before the expression was coined," and that "risk" is "an understatement of the entanglements" that ensue as "we live with non human entities brought into our midst by laboratories at MIT and Monsanto" (2001c). Like Beck, Latour stresses that "nothing is left of this picture" of closed sites (laboratories) in which small groups of experts scale down or up phenomena that they could repeat at will through simulations and models, and then scale up, diffuse, or apply in the world and teach to the public in a trickle down manner. Instead the "lab has extended to the whole planet, instruments are everywhere" and one needs a new definition of sovereignty in which there is "no innovation without representation." Despite his admiration for Dewey and American Pragmatists, Latour suggests that the United States is still too powerful and too steeped in inherited modernity, and Asia, Africa, and Latin America are still too full of dreams of being modernized; so that it falls to Europe to tackle the task of "adding technical democracy to venerable traditions of representative democracy," and that Europe's efforts to find a workable "precautionary principle" ought to be understood (using again a U.S. referent) as "no innovation without representation" meaning informed consent (2001a).

ANTHROPOLOGICALLY INFORMED ETHNOGRAPHIES OF SCIENCE AND TECHNOLOGY (1980s–PRESENT)

Anthropologists in the 1980s and 1990s tended not to start from science and technology studies, but encountered the need for them. Two genealogical traditions, and historical horizons, come together in this encounter. First anthropologists bring with them the ethnographic and social theoretic traditions described in the first section, finding the intellectual need for science and technology studies in the debates about the changing worlds of modernity (or modernities). They often traced their differences with SSK, SCOT, and ANT to those alternative ancestors of the 1930s–60s and their concerns sketched in the first section.

More importantly, the anthropologically informed tradition of ethnographies of the sciences and technologies began to form during the 1980s and 1990s, in puzzling out together with technoscientists in the field the nature of the rapid changes within which all were working. With the exception of Traweek and Haraway (and Latour), few came directly from science studies. Some came from medical and feminist anthropology (Emily Martin, Rayna Rapp) and were invited after their ethnographies appeared into science studies meetings, learning to enjoy an additional affiliation. Some came from French theories of modernity (Rabinow, prior to producing *Making PCR* [1996] had written the Foucault-inspired French Modern [1989]). Some came with influences from feminist postcolonial theory (Kim Fortun claims her work [2001] has been more influenced by reading Gayatri Spivak and Drucilla Cornell than Haraway or Latour). Sciences studies took on the role that critical theory; feminism, media studies, cultural studies, and postcolonial studies had performed for an earlier generation of anthropologists in the 1960s.

Hence, the ethnographies produced by these scholars look different from those of the SSK, SCOT, or ANT tradition. They have a wider range of actors, institutional accountabilities, political economy and media focus, class-linked cultural analysis, and other interests. What makes them "science studies" as opposed to just general anthropological works is that they also exhibit an intense interest in the materials, tools, technological assemblages, and epistemic objects of the sciences and engineering technologies, and how these in turn structure the world in nonintuitive ways. This often required investigation in tandem with the scientists and engineers who often share parallel puzzlements and concerns, even as they add to the patchworks and work-arounds, new circuits, experimental systems, data mining correlations, conceptualizations and heuristics of technoscientific worlds.[38]

New reflexive social institutions for decision making surrounding emotionally charged technoscientific issues provide another focus of attention. This focus leads beyond accounts of policy debates to ethnographically curious social and cultural analysis of the many actors, interests, perspectives, and cultural commitments that are often put into dramaturgically rich spaces of repeated, and recursive, tournaments of ethical decision making. Such institutions include new forms of ethical rounds in hospitals performing organ transplantation, heroic end of life interventions, and other contested medical procedures. They include the evolution of ethical guidelines for clinical trials around the world. They include differing civic epistemologies and assumptions about such research arenas as genetically modified foods, stem cell research, or xenotransplanation that get played out in commissions of inquiry, parliamentary debates, court decisions, and global trade conventions. And they include in the management of software innovation, and networked worlds, what Chris Kelty has called recursive publics (see below).

There is a second, more STS difference between the anthropologists and SSK style ethnographies, which also has to do with how the two sets of actors seem to have come to science studies. Physics continued to provide the key exemplary field for SSK as the "hard science" to show that it was cultural and socially constructed; the focus remained on a problematic of "fact making" inherited from an epistemology-centered philosophy of science. But it was the rise of molecular biology and biotechnologies in the 1980s, and then the computer network and web technologies in the 1990s that began to draw the attention of anthropologists as two technoscientific fields of innovation without which one could not understand the broader events, underlying rationalities, and ethical enrollments and disqualifications of emergent forms of life around us. These emergent forms of life entailed fundamental changes in the legal system (IP rights), the market (the introduction of venture capital and new relations between government, university and industry), the sense of physical body and social self (operating in virtual as well as real lifeworlds), and the increasing comfort with the double worlds of ordinary (family, sensory, psychological, and other sociality located) versus scientific (instrument-mediated, systems integrated) epistemological common sense about the composition and attachments of the world.[39] (A third emergent arena only beginning to take off in the 21st century is that of environmental and ecological knowledges seen as sites requiring not only interaction of multiple expertises or sciences and technical tools but also requiring systems analyses beyond the localities and punctuated industrial accidents or environmental disasters of earlier work.)

Older concerns with technological systems (electrification, irrigation, fish stocks, agricultural production, food processing and transport, energy production and transmission, and infrastructural development for the Third World), medical systems (traditional, alternative and modern, and experimental and regulated), physics (cosmology, accelerators, quantum mechanics, and relativity as epistemological challenges to everyday experiential worlds) took on an archaic feel but could be reinvigorated by refocusing anthropological questions through the lens (or new epistemic common sense) of the biotechnological, environmental, and informatics fields. Thus, for instance, the life sciences industry reframed studies of the history of medicine and epidemics. Bacteriology laboratories at the turn of the 20th century were now reanalyzed as key cases in a historical series of laboratory science sites from the 17th-century Royal Society to contemporary molecular biology labs that provided new ways to analyze the conquering of epidemics (Hammonds 1999; Latour 1988).

More importantly, the new life sciences made old distinctions between basic versus applied sciences harder to maintain, and the hostility toward histories of biomedical fields exhibited by history of science enclaves (such as the Dibner Institute for the History of Science at MIT) perverse. At issue was also the requirement of new fields such as regenerative medicine to promote a tight collaboration between very different fields of expertise, a nexus analogous to anthropology's traditional interest in cross-cultural translations and practices. Similarly, technological systems again took on renewed salience, with the internet, viral pandemics (HIV/AIDS, multidrug-resistant tuberculosis, or SARS), new media technologies, global financial systems semiopaque to financial traders and to the businesses financed and traded alike, or to the countries' stock exchanges and currency markets. Physics too is being reimagined via anthropologies of mathematical modeling and analyses (Graham and Kantor 2007; Sha 2005) just as physicists themselves have migrated into the life sciences with their cultural presuppositions of how to analyze and model things and relations.

STS-styled finance studies, for example, is one of a set of new topic areas emerging from a need to understand the political economy of biotechnologies and other technoscientific arenas (Dumit 2007; Petryna 2005; Sunder Rajan 2006), and as a field for which the application of SSK type analyses seems also well designed (Knorr-Cetina 2002; Lepinay 2005a, 2005b, 2005c, 2006; MacKenzie 2006; Riles 2004).

Although the anthropologically informed ethnographies of science and technology of the 1990s and early 21st century adopt many of the same tools or genetic elements, they often differ from SSK, SCOT, or ANT ethnographies in terms of audiences they address, the arguments they oppose, and the degree to which they address the questions of the genealogy about cultural skeins and sensibilities, epistemological objects and configurations of differently situated modernities.

Biology and the Life Sciences

One of the key arenas for the development of an anthropology of science and technology has been biology and the life sciences precisely because the science itself, as well as its institutional, conceptual, technical, legal, and ethical components, seemed to be rushing quickly beyond the pedagogies in which everyone in these fields had been trained. In addition, these rapid changes in the life sciences have more general implications for the common sense of personhood, politics, and ethics. The "molecular vision of life" (Kay 1993), understanding the transitional nature of the idea of the gene (Kay 2000; Keller 2000) and the way in which the language of information technologies colonized but did not satisfy the "cracking" of the biochemical code (Kay 2000), has led to a politics of health in which we experience ourselves biologically as patients-in-waiting (Dumit 2007), neither just healthy or ill but as carriers of risks and susceptibilities that make us, our organs, our tissues, our cells "bioavailable" (Cohen 2001) for economic exploitation, for reengineering the body and intimate connections to family and others, and for politics beyond illness and health, and beyond old notions of good and evil (Nietzsche 1886). There are new emergent forms of regulation, choice, and decision making, sometimes reinforcing and sometimes reworking older cultural ideals or inequalities (Biehl 2005, 2007; Cohen 1999, 2001; Fox and Swazey 1974, 1992; Petryna 2005; Rapp 1999; Sanal 2005).[40] Emergent forms of life are both biological forms and social ones. Nikolas Rose even suggests an elective affinity, in the manner of Max Weber, between a novel "somatic ethics" and the spirit of capitalism, which "accords a particular moral virtue to the search for profits through the management of life" and "opens those who are seen to damage health in the name of profit to the most moralistic of condemnations" (2006). Although this is perhaps a bit too "orthopedic" (after all Weber found a series of five elective affinities that went into the spirit of capitalism), the intensities and jouissance of the ethical debates and dilemmas at the intersection of new technologies in the life sciences are indeed a moral terrain, or set of ethical plateaus, on which new reflexive social institutions are emerging, and to which anthropologically informed ethnographies can contribute.

Anthropologically informed ethnographies, including historical ethnographies and multisited peregrinations through the distributed sites of biotechnological production (e.g., Sunder Rajan 2006 for the United States and India; Heath et al. 2004 for "genetic citizenship" groups, based on having, being a family member of, or being carriers of susceptibility for, such conditions as Marfan's Syndrome or achondroplasic dwarfism) have been creating a mosaic of jeweler's-eye accounts of the recombinant, evolving forms of patient advocacy groups and health care providers, the market and government regulation, national competitions over potentially economically productive biotechnologies and transnational cooperation in such large scale and high throughput technological projects as the Human Genome and HapMap Projects, along with tense North–South relations of biocapitalism, threats of biopiracy, and differential clinical trial ethics and promises of benefit for different populations.

Scientific fields have, of course, been transformed dramatically by new machines (as in the case of the Applied Biosystems 3700, high throughput sequencers, that transformed the Human Genome Project from a public endeavor to a public vs. private competition, raising moral as well as economic and legal IP rights questions [Sunder Rajan 2006]), as well as by experimental systems (Rheinberger 1997) and by experimental systems that can be turned into biological tools (Cambrosio and Keating 1995; Rabinow 1996). Ethical dilemmas have become no longer containable only through self-policing by scientists, as had been the case with the recombinant DNA technologies in the 1970s (the Asilomar Conference of 1975 leading to NIH rules for containment facilities, that were relaxed with experience). This is partly because of the vast amounts of money in play in a field that in 20 years had transformed from one in which at least academic biologists steered clear of entanglements with corporate profit drives, to one in which almost every successful academic biologist is involved in a company as a necessary means to protect patented discoveries and produce them in forms that are no longer merely experimental but can be used, licensed, traded, and put to therapeutic use. Biology has been transformed from a republic of science in which the flow of information (at least in academic settings) was largely free, to one in which one always tries to patent before publishing, and much data is closely held and no longer freely available. At every level, there seems to be not just small changes, but changes that synergistically accumulate toward complexly interactive systemic change.

Ethnographic and historical ethnographic work continues on model systems (Kohler 1994 on the Drosophila fruit fly, Rheinberger 1997 on the rat-liver experimental system, Creager 2002 on the Tobacco Mosaic Virus, Haraway 1997, and Rader 2004 on the production of standardized genetically modified mice for research), on reproductive technologies (Franklin and Ragoné 1998; Franklin and Roberts 2006; Hartouni 1997; Martin 1992; Rapp 1999; Thompson 2005), and on epistemic objects (Aryn Martin on chromosomes 2005). Newer work on using living tissue as tools in biology (Landecker 2007 on immortal cell lines), on robotics and systems biology (personal communication, Fujimura, April 2007), on genetically modified foods and stem cell research (Jasanoff 2005) cannot be contained within the walls of the laboratory, but necessarily entail cultural and social entanglements.

The parallel with the 1940s phenomenology discussions on the inherent indexicality of language (referring to the world outside the linguistic signs, and thereby destabilizing efforts to get to a stable underlying ontology, transcendental a priori, or invariant universal truth) are striking. Immortal cell lines that had been regarded as neutral tools in the 1950s, became racialized in the 1960s, and commodified in the 1990s (Landecker 2007). A-life experiments with "genetic algorithms" to explore complexity theory, however superficially for the science, were often talked about in terms of U.S. folk theories of kinship (Helmreich 1998). Computer algorithms now were being experimented with to model biological processes and, thus, to overcome excessive reductionism in biology (systems biology), while biochemical elements were being algorithmically experimented with to make new biological systems and new biomimetic devices (synthetic biology). The translation of computer cultures into biological cultures is not easy, and is the source of much synthetic and systems biology corridor talk about blindnesses and insights of the respective engineering versus life science styles of thought. This should provide a wonderful contested cognitive space for anthropological mapping, as were the earlier contestations between cryptographic efforts by physicists to "crack" the genetic code versus the biochemists who eventually began to unravel the complex biochemical cascades and pathways (Kay 2000). Other such interdisciplinary spaces include the kinetic ways crystallographers who with 3-D simulation algorithms figure out functionally significant complicated folding patterns, that wet biologists must then prove out (Meyers 2007).

These biomedical, bioscientific, and bioengineering terrains include ethnographic work on institutional innovations since the 1980s (Rabinow 1996, 1999; Sunder Rajan's *Biocapitalism* [2006]; Sunder Rajan et al. *Lively Capital* [in press]);[41] statistical strategies for clinical trials that ideally enroll everyone as "patients-in-waiting" and objects of "surplus health" extraction, pioneered by such cholesterol lowering drugs as Lipitor (Dumit's *Drugs for Life,* in press), or that capitalize on "ethical variability" across global populations in the search for drug naive populations (Petryna 2005; Petryna et al. 2006). Such projects use statistical sets of single nucleotide polymorphisms that can signal a predisposition for the possible increased risks of various diseases, and that can capitalize populations for biomedical research, as pioneered by Iceland's DeCode Genetics (Mike Fortun's *Promising Genomics* in press). The resulting databases can be used to manipulate physicians and consumers through "detailers" and statistical monitoring of pharmaceutical companies (Lakoff's *Pharmaceutical Reason* [2005]; more generally, Rose 2006, and the new journal *BioSocieties*).

Institutional accounts of the creation of molecular biology as a discipline (Kay 1993), the shifting uses of metaphors and rhetorical forms in the conceptual structuring of the sciences and their imaginaries (Doyle 1997, 2003; Keller 1995), the creation of new material-semiotic objects, such as oncomice, and other engineered research animals (Haraway 1997, 2003, in press), as well as a vision of how we now are beginning to write with biology, rather than merely discover it, creating biologicals that have never previously existed (Rheinbereger 1997) are transforming the ways in which we understand the relation between technoscientific production, society, and our biological and ecological conditions of existence.

What is perhaps distinctive about these works is the degree to which they are based on working with, rather than objectifying, scientists and their work, adopting precisely the opposite stance that Latour and Woolgar adopted in *Laboratory Life* (1979), adopting a more anthropological insider–outsider tacking back and forth. Rabinow found a key insider patron to work with (Tom White, the scientist-manager of the research projects in Cetus Corporation that led to the transformtion of the polymerase chain reaction (PCR) from idea to experimental system to marketable commodity; Creager, Kay, Landecker, and Sunder Rajan come from backgrounds in biology, and Rheinberger continues as a working molecular biologist as well as a trained historian of science; Haraway comes as a trained historian of biology with social democratic and feminist commitments, with an eye to seeing up close, ethnographically, technically, and conceptually how things might be done otherwise.

A second possibly distinctive feature is the mosaic nature of the work: that no monograph or study stands alone, but that they contribute to a series of studies analogous to old area studies projects in which a number of people would collaborate by working on different aspects or locations. No study is a microcosm; rather each is a piece of the larger puzzle.

But even more important are the conceptual tools, and the institutions for decision-making about unprecedented dilemmas or technological dangers.

Material-semiotic objects is a particularly interesting idea: an object whose creation changes the way the semantic system operates. Experimental systems (in contrast to testing devices that reliably reproduce the same result over and over) generate the novel through differential reproduction. Experimental systems differ from ideas (the scandal of giving Nobel prizes to an idea but excluding the people who created the experimental system that made it to work); and standardized marketing kits (or tools) are yet something else having to do with entanglements of standardization, and market share.

Networked Worlds

Computers, software systems, the Internet, and local networked systems are all part of a key site on which "the postmodern conditions of knowledge" have been puzzled out. Intimations, even seismic rumbles, in the humanities began, not only with structuralism and linguistics (which in their Lévi-Straussian and Chomskian forms claimed ambitions of integration with the neurosciences, mathematics, and computer or machine languages) but also with Jacques Derrida's *Of Grammatology* (1976), which argued that a reconfiguration of the general economy of writing, codes, and programs were creating new spaces for the human sciences and their engagements with the natural sciences, on the one hand (esp. molecular biology and the algorithmic or programming approaches of the computer sciences), and, on the other hand, with philosophy (meaning the assumptions and presuppositions that go under the names of metaphysics and ontology). Indeed, computer scientists, including computer game designers, would soon call that which they write "ontologies." Ontologies became a language game.

Jean-Francois Lyotard's (1979) report, "The Postmodern Condition: A Report on Knowledge," for the Quebec university commission, would insightfully identify the multiplicity and performativity of local language games, which would be enabled by software programs. They would functionally replace or "bracket" the hegemonic master narratives of the march of Reason, History, Progress that had disciplined the Cold War period, dating themselves back to the Enlightenment of the French revolutionary period, if not (as Derrida argued) the whole logocentric tradition of philosophy from Plato to Heidegger. Bill Readings's (1996) 30-years later follow-up, *The University in Ruins,* argued that the university is being cut adrift from its nation-building functions (symbolically centered on humanities' canons in standardized national language literatures and histories) in favor of audits and accountings of performativity and productivity (and "centers of excellence") for global competition. Henri Lefebvre (1967) was only one of many who feared the emergent world as one of the cyberanthrope, in which cybernetics, machinic Chomskian and structural linguistics would bring about even more surveilling and controlling, "totalitarizing" and "anti-humanist" cultures and societies.

But in the real world of ethnographic detail and anthropology from a pragmatic point of view, life and code are much more full of intrigue, puzzling, and gaming, involving plenitudes of passions and reasons, hacks and bugs, patches and work-arounds, values and interests, social imaginaries and institutional demands. It is a world, in Deleuze and Guattari's (1980) vocabulary, of assemblages rather than unified machines, freed from the state apparatus, "available for a postmodern pragmatic anthropology" (Rajan 2002:36; see also N. 32).

A few recent ethnographic accounts provide strategic access to these worlds. Chris Kelty's (2007) rich account of free and open software movements, the efforts to create open commons (for education, biodiviersity, medical data, scientific data and results, music, text, and video), digital archives and libraries, copy-left adjustments to IP law, and open access publishing not only describes and analyzes how such efforts are incrementally evolved as "experimental systems," but more generally he poses them as a new form of reflexive social institutions that he calls "recursive publics." This is a mutation of the 18th-century public sphere created through newspapers and coffeehouse debates with its regulative ideals of rational debate of public issues in spaces between civil society and the state (Habermas 1962), and of Dewey's notion (1927) of the public as the unintended consequences of policy making, which the experts have failed to see or anticipate. A recursive public, Kelty writes, "is vitally concerned with the material and practical maintenance and modification of the very means of its own existence as a public, as a collective independent of other forms of constituted power" (2007:2). It is constantly modifying, standardizing, remodifying, and experimenting with its technical standards and protocols, coordinating the various layers of volunteer contributed software, debating the cultural significance of changes to code-enabled infrastructural options, monitoring the portability of academic and commercial code, and pressing for ways in which the law and market can help maintain rather than inhibit openness through copyright and trade secrets. It is, thus, not only a reflexive social institution but also "raises questions about the invention and control of norms and the forms of life that may emerge from these practices" (2007:21). Recursive publics, he suggests, come to exist "where it is clear that such invention and control needs to be widely shared, openly examined, and carefully monitored" (2007:21).

To accumulate the details that compose his account, Kelty invokes contemporary anthropological fieldwork's "distinctive mode of epistemological encounter . . . suited to a problematic of emergence." Such encounters are multisided and in situ, but also mine the vast on-line archives and discussion lists (2007:22). In so doing, Kelty is able to access the normative and cultural dimension that the legal constitutional scholar Lawrence Lessig deals with least fully in his recognition of four key kinds of tools—law, market, code, and norms—that can be used to configure the Internet and other networking tools (1999, 2001, 2004).

Gabriele Coleman (2005) engages with the Debian Project, an open source distributor of Linux, and Anita Chan is currently doing fieldwork in Brazil, Mexico, and Peru, studying efforts to mandate government uses of open source systems such as Linux. Microsoft and other corporations are responding to the competitive popularity of open source by making some of their code partially open as well. Linux has proved to be not only popular among hackers and geeks, but is also widely used in mission-critical large-scale tasks. It is interesting that geeks have been less interested in making the front end of these programs more user friendly to nongeeks. Perhaps this is another cultural index of open but meritocratic or competence-based norms of admission and competition that goes along with the generally libertarian attitude toward the world.

At the frontiers of emergent forms of dependence on computer code and databasing are reliability studies and new forms of knowledge generation that use large data sets as experimental systems. STS scholar Donald MacKenzie (2001) explores the ambiguities and problems in the internal validation of computer models. Fortun and Fortun (2007) explore the emergent informatics field of toxicogenomics where various databases are experimentally cross-mined for possible correlations, patterns, and interactive effects. Schienke (2006) similarly explores simulations at three scales in efforts to model complex ecologies and environmental problems in China. Bowker's survey of memory systems (2005), as well as Bowker and Starr's work on classification systems (1999) sketch a terrain for this larger entry of informatics as the software of our emergent distributed knowledge systems, something that in a philosophical register, Lyotard (1979) foresaw, if only partially, as one of the conditions of postmodern knowledge.

* * *

In sum, the third genealogy is composed of investments in the worlds beyond the lab, a problematic of emergence, and an anthropologically informed ethnographic method of epistemological encounter.[42] Although it has begun to reengage the worlds beyond Western Europe and North America, the reconstruction of the cross-cultural, geographically distributed, linguistically accented, and historically varied anthropological project is only just beginning to unfold.

IV EMERGENT COSMOPOLITICAL TECHNOSCIENTIFIC WORLDS OF THE 21st CENTURY

At the Institute of Technology of Bandung (ITB), an innovative generation of computer scientists has tackled the challenges of networking the vast rural areas of the Indonesian archipelago with extreme low cost wireless technology, guerrilla education, and a move into the Ministry of Technology and Research.[43] At the Institute of Physics and Mathematics (IPM) in Tehran, a remarkable group of scientists helped keep the scientific culture of Iran alive through a period of cultural revolution when the universities were closed and Islamically purged.[44] It was the first site in Iran to be connected to the Internet, and is home to a world-class string theory group. Iran also has developed Bt rice as well as industrial scale tissue-engineered propagation for date palms and other fruit tree. It has; and has experimented with new social models for paying donors for kidneys and providing transplants free, and for WHO-designated best practices programs of HIV/AIDS triangular clinics.[45] In Egypt an experimental farm built with technosavvy combined with Rudolph Steiner and sufi ideology, has not only proved it can grow and market organic crops, but has also maneuvered the Egyptian government to ban cotton pesticide crop dusting and support healthier growing techniques.[46] In Taiwan, a cadre of biostatisticians has inserted itself as power brokers in the disputes over the International Convention on Harmonization for global clinical trials (Kuo 2005). In Brazil, tower experiments in the Amazon to determine whether the tropical forests are carbon sources or carbon sinks are interpreted differently by U.S., European, and Brazilian scientists. The 600-plus scientist Large-Scale Biosphere Atmosphere Experiment Program is intended to chart the sustainability of the Amazon ecology, the role of the Amazon forests in the global carbon cycle and, thus, in regulating the global environment, and to train a new generation of Brazilian global environmental scientists who can work from contexts independent of the currently hegemonic U.S. and European assumptions about how forests work, one of the contentious North–South divisions over the global political economy (Lahsen 2001, 2004, 2005; Lahsen and Pielke 2002).

These and numerous other initiatives constitute the terrain of new genealogical and network structures for the anthropology of science and technology studies. The historical horizon is quite different from that of colonial, development, new nations, or even postcolonial studies (e.g., Grove 1995, 1997 on colonialism and environmental knowledge; Ihsanoglu 2004 on science in the Ottoman Empire; Mitchell 2002 on expertise in Egypt, Pyenson 1989 on colonial science in Indonesia; Stuchtey 2005 on science in European empires; Jones 2004 and Watts 1997 on imperialism and disease; Edney 1997 on development of cartographic techniques through the Great Trigonometrical Survey of the British East India Company; and Bayly 1996 on information networks in British India), though the lessons learned and institutional legacies from those frames of study (and of policy making) remain important. So too nostalgic pride in prehistoric, ancient, or medieval rhizomes of long and polygenetic histories of local and civilizational knowledges remains symbolically important,[47] occasionally contains intriguing scientific or technological curiosities (the ecologically efficient desert irrigation systems of the Nabateans, the conversion error between Arabic and Roman miles as the explanation of why Columbus's estimate of the earth's size was 25 percent smaller than that of the correct one by Eratosthenes [I. Fischer 2005:278–286]), but is most useful when such studies can identify local ecologies, synergies, and networks of knowledge production.

The global initiatives of the 1950s hopes for cheap nuclear energy (Atoms for Peace), the International Geophysical Year (1957–58) and other such global foci of attention on scientific knowledge, and the 1960s space programs (in India and Indonesia) still have legacies around the world today, as do efforts by newly independent nations to build scientific research and educational infrastructures. These include in India the Tata Institute for Fundamental Research in Bombay, and the Space Science Research Center in Ahmadabad, and the Indian Institutes of Technology.[48] In China, they include the algae biotechnology marine research centers, rocket programs in China, and now burgeoning biotechnology efforts.[49] They include science cities and science and technology parks, such as the Korean Advanced Institute for Science and Technology, KAIST and science city at Deojeung and Tskuba in Japan, with its KEK physics accelerator (being a sister development to Irvine, California, as a planned science city, physically similar but with different dynamics). In Iran, they include the technical universities such as Sharif University, the Institute of Theoretical Physics and Mathematics, Amir Kabir University, Modares Tabataba'I University, and the Institute of Advanced Studies for Basic Sciences. In Indonesia, they include the ambitious effort to build airplanes, ships, high-speed trains, and automobiles, as well as endeavors in molecular biology, agricultural biotechnology, astronomy, and ecology.[50] None of these were smoothly accomplished, and require a cosmopolitical perspective to understand how they emerged and what the conditions of possibility for the future are.

The new generation of ethnographies of scientific and technological developments, especially in the worlds outside Western Europe and North America, is part of a cosmopolitical technoscientific world, where one needs an ethnographic eye to clearly see the political, cultural, technological, financial, institutional, and human capital building blocks and barriers. Generalized frames of postcolonial relations, for instance, while they serve well to highlight legacies of inegalitarian and dependency relations, cannot explain the successes and growth points of new developments.

With today's shifts in scale, changes in chronotope, spatial relations, and social organizational forms facilitated by the Internet and other communication, transportation, and dissemination modalities, a more detailed, ethnographic eye is required. Anthropology per force is becoming a third space, a space of comparative and entangled frames and of emergent forms of life (Fischer 2003). Differential and dialogic epistemic objects appear in agonistic, competitive and transnational relationships; civics and ethical discourse shift from universal rights and matters of fact to matters of concern, ethics of care, living with alterity, and the face of the other (Fischer 2006; Fortun 2007; Haraway 1991, 1997, 2003; Latour 2005a). Although STS studies are gradually beginning in many places—at the Institute of Technology at Bandung, the national Tsing-Hua and National Min-Yang Universities in Taiwan, Tsing-Hua in Beijing, the National University of Singapore, Sharif University and the Institute of Philosophy in Tehran, the Universidad Nacional de Colombia, and at various places in India[51]—these programs often have to struggle against older paradigms of study that emphasize catching up, or center–periphery relations. As the topics in the opening paragraph of this section indicate, these are not always the most illuminating or useful in the present context.

What makes these sites around the world not merely extensions of postcolonial debates but instead switching points within third spaces is that they have the potential for transforming science, policy, and cosmopolitics both in their targeted locales and beyond. For example, geographical information systems (GIS) and other database, mapping, and networking modalities provide material technologies for counter mapping, epistemic object creation, and enunciatory community development (Callison 2002, 2007; CRIT 2006; Schienke 2006). Mumbai's Critical Research Initiative Trust (CRIT)'s Mumbai Free Map, for instance, makes public ownership deed, rents, and pricing data, which previously was available only to developers, shifting some informational power into the hands of local communities so that they can participate in or contest municipal and developer plans, and even raise their own funding for new forms of housing and services. A digital assemblage of information about developers, miners, environmentalists, cultural archivists, artists, and elders, in principle, could provide a similar platform for public debate among the Tahltan of British Columbia; or for Inuit filing environmental and human rights suits over climate warming (Callison 2002, 2007; Landzelius 2005 more generally on indigenous communities' use of the Internet). In China, digital tools for environmentalism may help preserve ecosystems, provide visual means to foster public pressure to reduce air pollution, and provide linkages between spatial information at different scales (Schienke 2006). Similar tools were once mandated, in the aftermath of the Bhopal chemical disaster, as worst-case scenario mappings for communities near chemical factories in the United States as part of right to know legislation (Fortun 2001). They are made available by Syracuse University's Transactional Records Access Clearinghouse (TRAC) to provide monitoring access for journalists and others on biased enforcement patterns of the U.S. Internal Revenue Service; FBI; Department of Homeland Security; Bureau of Alcohol, Tobacco, Firearms and Explosives; and Justice Department prosecutions. In Israel and Palestine, they are used by watchdog groups (B'Tselem; Applied Research Institute Jerusalem [ARIJ], Palestine Environmental NGOs [PENGO]) to monitor and expose house demolitions, land expropriations, olive grove destruction, and road blocks (Fischer 2006).

What makes these more than just new technologies for local community organization is their global connectivity, highlighting the frictions (Tsing 2005), speed bumps (Sunder Rajan 2006), or time "out-of-jointness" (Negri 1970) that form the changing grounds of governance. Conservation biology in Indonesia (Lowe 2006; Tsing 2005) provides one preliminary example of shifts in cultural chronotope, cultural scale, and epistemic objects of governance. At issue are mentoring lineages in science and technology across the globe, flows of scientific personnel, the roles of transnational corporations not merely serving their own interests but acting also as sites of learning and experience for scientists and engineers who move in and out of various sized companies, academia, and government service; the establishment of new technology institutions, including incubators, science and technology parks, and universities (e.g., on Japan, see Low et al. 1999; on Korea, see Kim and Leslie 1998; and, more generally, Low 1998). Among the most interesting of new knowledges being produced are both the customization of technologies as they move from one ethnographic context to another, and the production of local knowledges that are important to global issues (such as biodiversity, climate change, mechanisms of cross-species infection, species ecologies, and food chains).

Technoscientific cosmopolitics (viewing the development of science and technology in a global—political, economic, material, and network—context rather than in simplified chains of histories of ideas within disciplines) is a terrain or ethical plateau that transforms traditional thinking about center–periphery and imperial power relations, about the role of domestic and transnational scientists mentoring lineages, about the circulation of scientists, and about the plurality of real world instantiations of projects, competitions, collaborations, and assemblages.

Prehistories for anthropologies of technoscience may usefully focus on key scientist or engineer leaders: C. K. Tseng, Tsen Hsue-shen, Homi Bhaba, Vikram Sarabai, B. J. Habibie, and Yusef Sobuti. But anthropologies of technoscience focus on the ways in which these lives and those of their institutional colleagues fit into larger patterns and networks of several kinds. As Marx remarked in the preface to *The Eighteenth Brumaire of Louis Napoleon,* historical, or here technoscientific, structures and structural change can be explained neither by reduction to great man stories, nor by deterministic stories of power relations (whether class, colonial, imperial, or postcolonial). At issue is the creation of consciousness, in his case of political consciousness out of inventive use of changing assemblages of political resources; here of technoscientific communities of understanding both among new generations of scientists, engineers, and physicians, and among publics at large.

Prehistories for anthropologies of technoscience may usefully also chart the colonial and postcolonial building of institutions: for example, Beijing's Tsinghua University, Taipei's Tsinghua University, Bandung's Institute of Technology (ITB) and its Bosscha Astronomy Observatory (Lembang), Bangor's Agricultural University (IPB), the Tata Institute for Fundamental Research (TIFR), the Indian Institutes of Technology, the Inter University Center for Astronomy and Astrophysics (Pune), the Pasteur Institutes (Tehran, Ho Chi Minh City, Tunis), the Abus Salam International Center for Theoretical Physics (Trieste), and the Third World Academy of Sciences (Trieste). But anthropologies of technoscience will also explore the relations between these institutions and the building of communities of scientific understanding: for example, the debate in Iran between those who argue that science textbooks should evolve Persian language vocabularies to stimulate fluid and culturally creative thinking (personal communication, Reza Mansuri, September 2006) versus those who argue that English terminology is the language of science and should be learned from the outset; the debate in Pakistan over the destruction of educational standards under the Islamicization policies promoted under the Zia-ul-Haq dictatorship (Hoodhboy 1991), and the somewhat parallel differences between the Ruzbeh schools in Zanjan and Tehran, the one producing secular scientists and intellectuals, the other producing religious ones (personal communication, Sobuti, September 2006); the role of the Sarabai Community Science Center in Ahmedabad; the role of cosmologist Penzana Premadi in a religion and science forum that also coordinates local astronomy groups in Yogakarta and Bandung (interview, September

2006), the role of cosmologist Mansuri in pioneering a popular astronomy and science magazine in Iran that coordinates local astronomy groups.[52]

Again, prehistories for anthropologies of science and technology may usefully chart the flow and ebb of national science policy initiatives, the building of science cities (Cyberjaya in Malaysia, Biopolis in Singapore, Hyderabad's Genome Valley and Cyber Towers, Bangalore's Silicon Valley and BioHelix,[53] Dubai Internet, Healthcare, and Media Cities and Knowledge Village), science and technology parks, the laying of fiber-optic cable, building of highways, manpower flows, brain drain figures, and recruitment strategies. But anthropologies of science and technology also explore communities of technological practice: Onno Purbo's strategy of bottom-up expansion of an internet user base and demand in Indonesia, the efforts of Iran to find technology park models in postindustrial divide Italy rather than in the massive top-down investment strategies of Tsukuba or Daejeong; the efforts of the national laboratories, new pharmaceutical company research and development efforts, and clinical trial hospitals in India to evolve hybrid organizational forms (Sunder Rajan 2006).

Prehistories for anthropologies of science and technology sometimes look to schools of traditional training as cultural roots for scientific breakthroughs as in identifying Brahminic astrological calculations for a putative root of Ramanjan's thinking, or Persian cultural patterns for putative roots for Ali Asghar Lotfizadeh's "Fuzzy Logic" (aka soft computing). But anthropologies and cultural histories of science and technology look more closely at alternative derivations for similar or differential results, and actual networks of influence. Loren Graham (2007) argues that varieties of (mathematical expressions of) general relativity were developed differently by Albert Einstein (a more complicated gravitational equation to allow for different coordinate systems) and by V. A. Folk (a simpler equation because of picking a particular harmonic coordinate system that made clear that the theory, in good Soviet Marxist fashion, was of absolute space–time or gravity, and not "relativistic" as Einstein agreed he had misnamed it). He argues in similar fashion that set theory was differently derived by mystical Name Worshippers in Russia (Dmitri Egorov and Nikolai Luzin) and by French rationalists (Emile Borel, Rene Baire, and Henri Lebesgue.) Fuzzy logic is perhaps a more interesting example. Introduced in the 1960s by Lotfi Zadeh, one of three prominent graduates of the first class of graduates of the School of Engineering at the University of Tehran, who pursued his career in the Electrical Engineering Department at Berkeley, fuzzy logic was initially a way of modeling natural language, relaxed the rules of Boolean logic, and became useful for control systems in a variety of arenas, initially for appliance manufacturing in Japan (Lotfalian 2004). What is interesting is how many Iranians have followed Lofi Zadeh as experts into the field, and how such soft computing upset the decade-long Japanese Fifth Generation Computer Project (1982–95) to develop a revolutionary large-scale parallel processing computer system. Although Japan would still go on to develop the world's fastest supercomputer (installed in 2002 at the Earth Simulator Research and Development Center, Yokohama, and used for climate modeling), the fifth-generation computer was derailed by the processing speed, memory capacity of personal computers, and distributed computing through workstations, as well as by soft computing techniques such as "fuzzy inference" and neural networks (Low et al. 1999; Markoff 2002).

The weave of transnational connections, lineages of mentoring across countries, brain drain and return, and historical knowledge bases is shifting and expanding. One third of postdocs working in U.S. biology labs are said to be Chinese nationals, many of whom are returning to China. Fellowships for Indonesian scholars are becoming more available in Japan and Australia, as they become less available in the United States and Europe, and Japan itself is beginning to export engineers to Asian countries as Japan moves its manufacturing abroad. Sharon Traweek (1996) has tracked some of the gender and cultural differences of physicists working at KEK in Tsukuba: the love of Americans for tinkering with equipment, the professionalized distance of Japanese from carefully machined equipment; the use of international postdoctoral fellowships for Japanese women scientists to evade the patriarchal hierarchies of labs in Japan, build intellectual capital and networks that can then be used to get ahead at home. Sarah Franklin (2007) engagingly shows that Ian Wilmut's team that developed somatic nuclear transfer "cloning" in Scotland (producing the sheep Megan, Morag, and Dolly), occurred in the context of a long historical tradition of breeding a diversity of sheep in Britain. As interesting, however, is the fact that the second in the world to develop a human stem cell line was a team of Benjamin Reubinoff of Israel and Alan Trouson of Monash (Melbourne) and Singapore (who pioneered IVF technology in Australia and studied at Cambridge): the network is global and situates itself where opportunity arises.

At issue is not just a reconfiguration of political-economy competitions, but also a series of new ethical demands and configurations, highlighted by the stem cell debates. Franklin quotes Wilmut, "In the 21st century and beyond, human ambition will be bound only by the laws of physics, the rules of logic, and our descendants' own sense of right and wrong" (Franklin 2007:32). Although he goes on to say "Truly, Dolly has taken us into the age of biological control," what is more interesting is the notion of ethics being defined by the future-anterior, by "our descendents own sense of right and wrong." This is indeed the challenge of designing reflexive social institutions that incrementally and recursively help us construct the publics forming around us. We do live in a new age of biological sensibility (not necessarily control), and one that through our expanding networked experiences are creating new kinds of recursive publics. The cosmopolitical worlds of technoscience are becoming ever more diverse, distributed, and dependent on a heterogeneity that both requires and enlivens anthropologies to come.

CONCLUSIONS: TRANSLATING LEGACY GENEALOGIES TO PUBLIC FUTURES

Four genealogies, like quadroscopic-lensed eyes, can provide complementary vision: cultural skeins and sensibilities; social worlds and institutions; technoscientific proving grounds; and spatially distributed, culturally heterogeneous, configurations of technoscientific assemblages. Metaphorically, these are like camera-lenses establishing long-shots; close-up ethnomethodological lenses; motion picture lenses for emergences and motion-detecting midrange theory; and wide-angle, close-up lenses for situationally located experimental systems. The cultural skeins, programming "object-oriented languages," emergent forms of life, and cosmopolitical marshalling of ingenuity tracked by anthropologies of science and technology productively complicate and make more realistic the demand for attention to the reconstruction of public spheres, civil society, and politics in the technoscientific worlds we are constructing within and around ourselves. No longer can we rest on broad claims about the alienation of the market, the technicization of life, or globalization. Just as we have moved from Mertonian sociologies of science to analyses of what scientists actually do, so too, we need to pay attention to civic epistemologies and cultures of politics as they are mediated by the paradox that the more networked, the more transparency, the more access, perhaps the less polis-like ability for localities to control local destiny (unless careful attention is paid to the infrastructural firewalls, speed bumps, accountability mechanisms, alternative valuations, sanctions, rewards, jouissance, intensities, sensibilities, and openness) and as they are transduced across the cultural switches of the heterogeneous communities within which the sciences are cultured and technologies are peopled with the face of the other.

NOTES

1. This article originated for a panel convened by the editors of *Cultural Anthropology* on genealogies of anthropology and STS at the Society for Cultural Anthropology meetings in Milwaukee in spring 2006. Many thanks to Kim and Mike Fortun and Kaushik Sunder Ranjan for critical

readings and suggestions during the several redraftings, and to members of the panel and audience, as well as a workshop with Sheila Jasanoff's students at Harvard's Kennedy School for questions and feedback.

2. I adapt the term from Ulrich Beck's 1986 work (1992), but intend also the notions of "mode two" knowledge (Gibbons et al. 1994) or "postnormal" science (Funtowicz and Ravetz 1992). Other allied notions include "communities of enunciation" (Fortun 2001), civic epistemologies (Jasanoff 2005), biology as civics (Haraway 1997), and "matters of concern" (Latour 2005a).
3. Suchman led a famous group of anthropologists, linguists, and others at XeroxParc which spawned the field of "work practices" studies. It was the beginnings of work by anthropologists in corporations, who now have their own professional organization Ethnographic Practioners in Corporations (EPIC). Sheila Jasanoff, the founder of the Science and Technology Studies Department at Cornell, trained as a linguist and lawyer, has been important in keeping the field focused on politics, power, policy, and the law. In recent work (2005) she has explicitly taken up anthropological ethnography as a tool of the trade.
4. Crucial to the techniques of writers such as Adorno and Benjamin was the notion of mimesis, of using the terms of an opponent but then showing how they can be exploded through their internal contradictions, how they lead to absurdities, or how they can be leveraged into quite other directions than the opponent intended. Adorno repeatedly used this tactic against Heidegger (see Hullot-Kentor 2006 for some beautiful readings and explications). Michael Taussig (1993) has expanded on Benjamin's ideas about the "mimetic faculty," a faculty that has often been connected with mimetic faculties in animal and pedagogical worlds. It remains one important strategy of the poststructuralists in the continuing strategy of dismantling the naive neologistic mythos of the Heidegger cult and similar legacies of the neo-ontological movement of the 1920s (see Hullot-Kentor 2006:236 and passim).
5. Magic words or slogan terms, as Fleck pointed out, are rhetorical ways that intellectual sparring teams mark out enemies. They are often constructed as caricatures with a grain of truth that radicalizes an opponent's position often to an absurd position that no one would own. Among some of the most important such terms of abuse in science studies are *positivism, postmodernism,* and *relativism* (mischaracterizing a methodological obligation to attend to "relations" among elements, or in anthropology, the obligation to understand a point of view and relate it to its sociological and historical context). Inversely "anti-humanist" and "anti-Enlightenment" are jaunty flags of temporary self-distinction, to make a point that has mutated into distorting labels taken literally.

   "Humanism" is used in a variety of ways. (1) The slogan that Nietzsche, Derrida, or Ronell are "antihumanist" strikes me as peculiarly parochial and philosophically indefensible. The slogan came about in the 1960s through1980s to characterize irrationalism (and so Nietzsche, if one reads him not as a critique of false pieties of normal religion and morality; sometimes psychoanalysis insofar as it shows we are not in control of our unconscious), and linguistic or rhetorical analyses (structuralism, poststructuralism) that show that we operate within codes that precede and exceed our intentions. It was a flag of structuralism and Foucault's "death of the author" against the failures of the Soviet Union (*The Gulag Archipelago* came out in French in 1974) and the Nazis (Heidegger's "Letter on Humanism") as false claims to fulfill "humanist" hopes; and a warning against mere claims of good intention in waving the flag of human rights and humanitarianism. In his argument with Sartre, Lévi-Strauss said Sartre's "classical" humanism of social consciousness needed to be replaced with a new form of humanism. One can argue (Christopher Norris has done so admirably over many books) that Derrida is a defender of reason, and is not anti-humanist; ipso facto for Ronell; and that the fact that the world is not simply mechanical, that our reason and our social systems are constantly under redirection is only to make what is human more precise, and less illusory. (2) Humanism, as I understand it, is a philosophical project of basing ethical, epistemological, and scientific arguments on human capacities, sensibilities, affect, and reason; rejecting supernatural dei ex machina, divine revelation, arguments from mere authority or mere tradition. (3) Historically, in the Renaissance humanism took the form of rediscovery of classical knowledge that often had metaphysical foundations such as the notion of *ousia* (substance) or *psukhê* (mind) A figure such as

Erasmus was able to satirize and criticize Catholicism while remaining Catholic, and remained a friend of Luther while refusing to become Lutheran; but with Galileo's condemnation and burning of his books, the humanist crisis came to the fore, shocking such figures as Descartes into recognizing that humanist freedom had lost out against a flow of history that was no longer in favor of bourgeois, civic, and humanist ideals, and would need the absolutist state as defense both against the nobles and revolts from below (Negri 1970). (4) The 18th-century projects of Kant and Fichte attempted to straighten out the metaphysics as well as insufficiencies of Humean empiricism. Fichte attempted to start again with "drive structures—of longing, of dreaming, of striving and so on" (Heinrich 2003:18). While the idea of universal human morals and modes of thought was part of these projects, and "Enlightenment" was meant to help human kind educate itself, universality was challenged by anthropologies of different cultures and the emergence of the notion of cultures in the plural (Sittlichkeit, Bildung, Kultur, Zivilisation) and "cultures as experimental systems" (Fischer 2007) each of the preceding terms in fact being a slightly differing epistemic object). In no way does this compromise the larger project of humanism. (5) Modern humanist societies and movements included pragmatists William James and John Dewey, scientists Julian Huxley and Albert Einstein, writers Thomas Mann and Kurt Vonnegut (who was until his death in 2007 the honorary president of the American Humanist Association).

6. William James's Varieties of Religious Experience (1902) remains an interesting exercise in parsing parapsychological phenomena as something that cannot be technically disproved and yet cannot be acceptable as scientific. The milieu of séances is vividly revived in Avital Ronell's (1989) study of Alexander Graham Bell. The Vienna Circle of philosophers, mathematicians, physicists, and social scientists attempted to clarify scientific language as being that which in principle can be subject to empirical testing, verification and falsification. They had close relations with American Pragmatists (logicians such as C. S. Pierce and Charles Morris, philosophers of the public such as John Dewey, physicists such as Percy Bridgeman who developed similar ideas under the name *operationalism*).
7. Paul Lazarsfeld, founder of Columbia University's Bureau of Applied Social Research (the successor to the wartime Radio Project), hired Adorno to help with the Authoritarian Personality project and studies of wartime propaganda. Lazarsfeld was trained in Vienna in mathematics (with a dissertation on the mathematics of Einstein's gravitation theory), was a junior student in the penumbra of the Vienna Circle, and also cowrote a pioneering ethnography, *Marienthal: The Sociography of an Unemployed Community*, with his wife Maria Jahoda, and Hans Zeisel (Jahoda et al. 1933). A pioneering force in sociology as a statistically informed discipline, he also trained Barry Glaser, the founder of so-called grounded theory or qualitative methods in sociology, very close to anthropological ethnographic methods.
8. *Essai sur la connaissance approchée* (1928), Paris: Vrin 1987, S.13, 284; cited by Rheinberger 2006:25.
9. The formulation, "differential reproduction" has become familiar in Rheinberger's work on experimental systems in molecular biology (1997), in Derrida's literary-philosophical deconstructions and reconstructions (from his 1966 "Structure, Sign and Play" on), in Gilles Deleuze's philosophies of new concept formation (from his 1968 *Difference and Repetition* on).
10. The physicist Ludwig Boltzman, among others, saw evolutionary biology (Darwin), as proving that life could be reduced to mechanical–physical principles. Others, drawing on organcism and vitalist ideas insisted that the complexity of biology could not be reduced to atoms and biochemicals. See Rheinberger (2006:ch. 1) for a brief overview.
11. See David Lloyd's (1989) "Kant's Examples" for a lovely account not only of the difference between Beispiel and Muster but also the circular temporality, pedagogical imperatives, and the bourgeois political historicity of Kant's "pragmatic anthropology." Scientific opinion is a sensus communis or doxa (common sense, both physical sensing, and a community of achieved sensibility and authority) that is created in a dynamic, dialectical temporality of anticipation (a "project" as Sartre would express it in existentialist language), a "happy union" (a glücklichen Vereinigung, happy union) between a future better understanding yet to come and a present preparation (suspended between Das Zeitalter . . . ein späteres Zeitalter), and in a collective

democratic endeavor of freedom that Hannah Arendt would specify as a condition of the human condition of plurality, a gradual building of a political space in which all are equal citizens, whatever their inequalities outside that space, a space that is moreover responsive to their (individual as well as in aggregate) different perspectives and situated experiences. The hierarchical laboratory is a pedagogical space in which the graduate student is trained to become a mature scientist, the equivalent of Arendt's mature citizen. It is the lab head who speaks as the free citizen of the republic of science.

12. Bachelard 1928: S. 297; Rheinberger 2006:29.

13. Two kinds of meaning were included as scientifically valid: analytic or structural or combinatorial logic; and in principle verifiable or falsifiable representations of the experiential world. Otto Neurath combined these discussions with the need for them to be not only grounded in" the practical contingencies of inquiry" but also in "the social dimension of knowledge production and transmission within the framework of historical materialism" (Uebel 1992:20). Uebel (1992) provides a useful review of the various positions debated in the Vienna Circle as a rebuttal to what he calls the traditional view of their position (i.e., the canonic view propagated through the various attacks on them). There are useful accounts of the historical and sociological context of the Vienna Circle In Uebel 1991 and Nemeth and Stadler 1996. All three volumes focus on Neurath but serve to give a more balanced account of the group's debates, agreements and disagreements, and historical horizons. Among these, it is worth recalling the rejection of Kant by the Austrian church and court as products of the French Revolution (Haller 1991:43), and the affinities in Vienna of on the one hand political Catholicism, natural law and authoritarian structure of government, and on the other hand the antimetaphysical enlightenment philosophy of the Vienna Circle with the theoretical foundations of social democracy (Stadler 1991:53). A case is also made for seeing Neurath as a precursor to Kuhn; and of course Kuhn's famous essay, "The Structure of Scientific Revolutions," was part of Neurath and Carnap's project of the *International Encyclopedia of Unified Science.* Neurath is known for his interest in using visual means of conveying information accurately to broad audiences (Neurath 1939).

14. The struggle morphs into debates over basic and applied science as the best way to generate new knowledge; large-scale engineering versus decentralized initiatives. At the beginnings of molecular biology in the Berkeley, University of California, San Francisco, and Stanford consortium in the 1940s and 1950s the determination was to pursue basic science; by contrast MIT's Health, Science, and Technology Program (HST) has prospered by pursuing a combined basic and applied science approach. MIT pursued a science-based engineering curriculum, while Germany built its industrial might through vocational engineering schools (see Lash and Urry 1994 on differences between Germany, England, and the United States). On the disastrous effort to replicate the Tennessee Valley Authority in southwestern Iran and the Helmand Valley of Afghanistan, see Goodell 1986; Fischer 1980). On large scale engineering projects in the United States and Russia see Graham 1998; Hughes 1998.

15. Known for his articulation of tacit knowledge, which would be ethnographically detailed by Harry Collins (1974), Polanyi's "The Republic of Science" (1962) is interesting as well for its account of science as a community of trust, beliefs, and passing down of knowledge by authority, a position worked out in historical ethnographic detail for the 17th-century Royal Society by Steven Shapin and Simon Shaffer (1985). Polanyi compares the republic of science to the double-handedness of British politics: on the one hand is the dominance of utilitarianism in British political theory, on the other is the actual dominance of Edmund Burke's "partnership of those who are living, those who are dead, and those to be born"—"The voice is Easu's but the hand is Jacob's" (Polanyi 1962:22–23).

16. The vocabulary of (un)veiling, clearings, getting beyond appearances and representations, facticity (quiddity in scholastic language), and the turn to poesis and self-awareness, all partake in a family resemblance which is, as one says, the metaphysical tradition of the philosophies that define themselves in terms of the ancient Greeks. Illuminationism (ishraqi) is a school of Iranian mystical philosophy stemming from the work of the 12-century Suhrawardi, which was popularized in the West by Henri Corbin (1960) and S. Husain Nasr (1964). Corbin is

also an early translator of Heidegger into French. More technical, rationalist, and less mystical accounts of Suhravardi are provided by Hossein Ziai (1990, 1992, 1996), which might prove a fascinating way to critique Heidegger and place him even more firmly within a scholastic metaphysical tradition than is usually recognized by merely noting the Christian theological traces and the legacies of his interest in mysticism (in his dissertation), his revolt against Catholicism, his turn to radical Lutheranism (searching for a "free Christianity" first in Meister Eckert and Luther, then in Dilthey, Kierkegaard, Schliermacher as Christian Protestants), and, finally, to a folk religion built around his own interpretation of Nietzsche and Hölderlin's poetry, complete with his own rituals around the fire (and with Hitler salute) and now posthumously with Heideggerians annually pilgrimaging to Freiburg and building forest huts in imitatio of the master. Iranian Illuminationism has a fascinating neo-Platonic account of symbolic forms (alam al-khayal, translated by Corbin as *mundus imaginalis.* It also has a fascinating technical deconstruction of Aristotelian logic, and a counter development of logic and semantics building on the Stoics and Megarian neo-Platonists. It also takes positions against Aristotle and Ibn Sina (Avicenna) in the discussions over the priority of essence (Being) over existence (viz. Heidegger's ontology vs. ontics), and develops a way to think about prerepresentational knowledge, which "results in attempts to unravel the mysteries of nature not through the principles of physics but through the metaphysical world and the realm of myths, dreams, fantasy and truths known through inspiration. The distinction between scientific knowledge and knowledge-by-presence is crucial for al-Suhrawardi, just as it is for Heidegger (in speech), who claims that the essence of human beings lies in their self-awareness, through the luminosity of their own inner existence" (Ziai and Leaman 1998). Although it is often claimed that Heidegger was secularizing Christianity, in fact he was seeking for an originary experience of religious being in the world, and for him phenomenology is about the speech that lets phenomena come to presence for the experiencing of self. As Theodore Kisiel (1993) and Christopher Rickey (2002) show in detail, for Heidegger Aristotle's phronesis (insight for action) becomes via authentic religiosity the Augenblick (instant of vision, blink of an eye), the lightning flash of authenticity, the "clearing" for presence to manifest. Walter Benjamin would use the notion of images flashing up in a moment of dialectical insight to quite different ends (Buck-Morss 1991) as also the notion of intoxication (Bolz and van Reijen 1996:57–58); Theodor Adorno would devote a small volume, *The Jargon of Authenticity: On German Ideology* (1973) to debunking Heidegger's notion of authenticity; and Jacques Derrida tirelessly showed how speech is not originary presence.

17. Bayh-Dole mandated that universities make their research available to the private sector by patenting and licensing, on pain that federally funded research results not so pushed into innovation development be reappropriated for patenting and licensing by the federal government itself. The idea was to stimulate the pace of innovation. The Chakrabarty decision allowed the patenting of an oil-eating bacterium, which then opened the patenting gates to a wide variety of process and materials patents that had not been thought to be patentable before. The effect is to both to stimulate private entrepreneurial innovation and to privatize information in the form of IP rights. Theoretically the patent system is supposed to make processes public in exchange for earning licensing fees; in fact it operates to make some information less open as "proprietary."

18. The myth and symbol school that helped establish American Studies provided a powerful way to establish the credibility of U.S. culture in contrast to European culture, and I do not mean to belittle their contributions. Leo Marx's *Machine in the Garden* (1964) remains a popular text (the pastoral as a critique of the industrial world), and Richard Slotkin's more recent books on violence in the U.S. mythos provide another well-received body of work (e.g., 1973). That Leo Marx should have written a sympathetic account of Heidegger (1984) is perhaps a token of affinity between Protestant transcendentalism, often with an Orientalist mystical tinge, in New England and mystical searchings in Europe that influenced Heidegger. But Heidegger's trajectory ought to provide a cautionary note, as the philosophical and ethnographic metabolizing of his legacy, I will argue here, has demonstrated. In any case, American Studies itself has divided between a more popular culture approach descending from the myth and symbol school, and

a more ethnographic, anthropological and social historical approach associated with authors such as Roger Abrahams (1964), Jose Limon (1994), George Lipsitz (2001), and Kathleen Stewart (1996).

19. Idioms of the 1990s have displaced the simplistic older debates about technological determinism. From computer programming we have become accustomed to talking of technological fixtures as either bugs or features (the same item seen as a negative or a positive). From business strategies, similarly, we talk of problems as providing new business opportunities, as in toxic waste providing opportunities for green technologies. Notions of constraints morph into leveraging, redirecting, and reconstructing.

20. There is a family of resemblances among narratives of alternative modernities (Gaonkar 2001), postcolonial analyses, and the dialectics among hegemonic grand narratives of history (Lyotard 1979; White 1973) and irrepressible counter or dissident "minor languages" (Deleuze 1975) of those minorities and small societies (much of the literature of Central Europe, such as Jaroslav Hašek's 1926 *The Good Soldier Schweik*) whose members feel they have been run over by history, reason, and progress. Ethnographers have worked in all three of these traditions and more can be translated into these traditions with a little bit of recontextualization.

21. *The Dialectic of Enlightenment* is a critique by "mimesis with a difference" of Heidegger's approach. Heidegger's 1954 essay is a response based on lectures from 1949–54 (see, e.g., McCormick 2002, whose account I follow here). For Adorno and Horkheimer, a key feature of the development of technology is the exploitation of others' work and capital, the production of appropriable and redistributable surplus value. State capitalisms of the 1930s extract surplus value from workers' labor, as did classical 18th- and 19th-century industrial capitalisms, but their imaginaries are no longer structured only around fantasies of individuals selling their labor freely or under coerced conditions to the disciplining invisible hand of the market, enforcing brutal competition among capitalists who cannot afford to be kinder to workers lest they go bankrupt. Instead a political logic has become incorporated through the work of mass parties, mass advertising, mass rituals, and the transformation of subjectivities from Oedipal family forms to ones governed by peer groups or projections of charismatic, perfect role models (political leaders, movie stars), what Freud similarly analyzed in his essay on "group psychology," and Adorno famously analyzed in his contributions to *The Authoritarian Personality* (1950). Patriarchal (monarchies) or patrimonial (imperial) forms of governance have been transformed by massification and new kinds of communication and control technologies, as have subjectivities.

22. In Psychology from the Empirical Standpoint, Brentano distinguished mental acts as having "intentionality," as being directed toward some object. The problems of human agency were central to discussions about the differences between the physical and social sciences (and their methods), and were taken up in various ways by Dilthey (intersubjectivity, Nachbild und Vorbild which Geertz would turn into English as "models of, and models for"), Husserl (all concepts are concepts for someone), Max Weber (one can construct "as if" ideal types to account for observed patterns of social action), C. S. Pierce (indexicality, iconicity, and symbolization; firstness (speaker), secondness (addressee), and thirdness (indexicals); and linguists (messages and sociolinguistic pragmatics).

23. See the similar thought about Husserl expressed by Sha Xin Wei (2005:79 n. 4), and Barbara Stafford's to retrieve a genealogy of thinking about preverbal cognitive images, or to deal with the "brain-in-the-vat" problem, namely "that the material world we live in is both real and unreal: a plausible fiction set up—imposed, as it were—by something more basic and prior to what we see, yet mysteriously corresponding to it" (Stafford 2004:315–348). She tweaks this genealogy of "ontologically enriched formalism" in the direction of neurobiology. Douglas Hofstadter (2007) does something similar in trying to model neurobiology in terms of self-referential loops and emergence. Sha—a consummate explorer of mathematics, electronic-sensor environments, and socialities—tweaks A. N. Whitehead's "lures for feeling" made from measure theory and topological dynamical systems" (and the work of others such as Husserl, Gilles Deleuze, Alain Badiou, and René Thom) in the direction of "an archeology of mathematics" and mathematical physics.

24. On the puzzle of Heidegger's charisma, Levinas, explaining his youthful enthusiasm for Heidegger, recalled that Heidegger's "firm and categorical voice came back to me frequently when I listened to Hitler on the radio" (Moyne 2005:95). Habermas, as well, said in a visit to Rice University, that he cannot read Heidegger without hearing the sound of Nazi rhetoric. And the French philosopher Maurice de Gandillac wrote in 1934 of the contrast in debate at Davos between Ernst "Cassirer . . . 'so circumspect, so discreet,' and 'the 'woodsman' Heidegger, paradoxical, lyrical, passionately one-sided," and his surprise at "seeing . . . the mass of German students fall under the spell [subir la charme] of the vehement philosopher in somewhat the same way as the German audiences today experience the Fuhrer's magnetism" (2005:95).
25. One can, of course, distinguish between transcendental and existentialist phenomenology (as Paul Ricoeur usefully suggested), and this was one of the axes along which Jean-Paul Sartre attacked Heidegger. Sartre's "cogito" becomes a "moment of responsibility," structured by a series of aporias (see Rajan 2002:58 and passim). But for Riceour, Merleau-Ponty, and other existentialist phenomenologists, Husserl is seen as having both tendencies.
26. See Bernstein (2002) for a nice account of how Arendt criticizes, by transforming, Heidegger's tropes, insisting on working toward a political realm of freedom that is constituted by the inherently different perspectives of human beings debating and thereby establishing their doxa (public opinions, worked out in public forums, ideally between institutionally equal citizens working through their inherently differently situated perspectives), working thus against Heidegger's solipsistic Selves for whom Mitsein and Mitdasein is only a generic or pregiven background and not an actual agon of social action historically and socioculturally located. Her grounding of the human being in speech and action "in-between" plural human beings and her Kantian notion of doxa parallel the anthropological development of the notion of culture (Fischer 2007). In relation to the mass technologies of totalitarian movements, she characterizes (thereby criticizing) Heidegger's account of Offentlichkeit or publicness (distancing, leveling, reduction to the common denominator, even "Das Licht de Offentlichkeit verdunkelt alles" [the light of publicness obscures everything]—just the opposite of hers—as a description of a degraded public arena in the administered state, one constituted as the Frankfurt School analyzed by mass advertising, mass politics, as well as mass industrial production. It is in the plurality of the human condition, even under such conditions, that Arendt argues possibilities always exist for initiatives of organizing otherwise. (Philosophically Arendt is reacting against her earlier adoption of the theological notion that freedom resides in fighting against fate and the desire to atone for sins that one could not help committing, so-called innocent guilt. See Leonard 2005:ch. 1 on Schelling and Oedipus, and the tragic tropes of German philosophy.)
27. This insistence on relations and relations of relations was already central to so-called British anthropology's "functionalism" or "structural-functionalism" (particularly as voiced by A. R. Radcliffe-Brown. The proximate source was Durkheimian sociology, but the more general source was the interdisciplinary language of structure and function in describing organisms and physical processes, including an effort to employ the notion of variance in mathematical functions. These were productive ideas for comparative studies of kinship and marriage systems (Lévi-Strauss 1963; Radcliffe-Brown and Forde 1958; Schneider and Gough 1961), political structures (Fortes and Evans-Pritchard 1958), and the like. Marcel Mauss was taken as a founding ancestor both by British social anthropology (his *Essai sur le don* was the very first text I was given as a student at the LSE in 1965) and by Lévi-Strauss who reconstructed him in terms of his own structuralism (1987). The effort, however, to specify a set of "functional equivalents" of different cultural and social solutions to a basic set of human needs, of course, quickly proved a biologically reductionist dead end, because there is no way to specify either an exhaustive list of needs, nor of the functional equivalents said to be whole or partial solutions to any of them (Aberle et al. 1950).
28. I take the phrase from the testimonial by David A. Nock about how he was directed to Kuhn by his teacher, the sociologist Arthur K. Davis, in his obituary for the latter (Nock 2002).
29. Tilottama Rajan (2002) makes a distinction between affirmative poststructulism (Barthes, Deleuze and Guattari, Gregory Ulmer) and a negative poststructuralism, which is more philosophical and continues to be concerned with the "loss of phenomenology," with the loss of

either a transcendental ego (the possibility of universal a priori forms of thought), direct apprehension or intuition of reality, or a metaphysics of being. It is this philosophical traumatic core, as a Lacanian Real, that he traces in Sartre, Derrida, Foucault, and Baudrillard, all of whom in his reading worry a "doubly barred" subject, barred from subjectivity (the Imaginary, phenomenology), and barred from objectivity (the Symbolic, Lévi-Straussian structuralism). This explains the rhetoric of dismissing Kantian or contemporary pragmatic anthropology as merely positivist, empirical, or ontic, and the fear that the integrity of philosophy as a discipline is threatened by the rise of the human sciences. But it is only one side of a rich set of inquiries into the structuring of discourses, which perhaps is a way of recuperating even negative poststructuralist meditations for affirmative poststructuralist readings. Indeed Rajan himself suggests that deconstruction and postmodernism functioned in the 1960s as a return of the unfinished project of phenomenology of the 1930s, and plots his account as phenomenology and structuralism being the unconscious of each other (p. 90). He cites Derrida's comment that Husserl's phenomenology "in its style and its objects is structuralist" because "it seeks to stay clear of psychologism and historicism" (*Writing and Difference*, p. 159; see Rajan 2002:100). Similarly he cites Derrida's assertion that deconstruction is always epistemic and affirmative, always concerns systems with a view to opening onto other "possibilities of arrangement" (Derrida, *Points,* p. 83, 212; see Rajan 2002:94). Similarly again, and citing James Miller, he notes that Foucault's early essay on Kant's *Anthropology from a Pragmatic Point of View* is the seed of *The Order of Things* (Rajan 2002:95). In this context, Deleuze and Guattari's revision of machinic imagery as assemblages, and the shift from representation to mediaality (also in Barthes, Ulmer, and Derrida) helps free the discussion of technology (as machinic, inhuman) from the state apparatus, and makes poststructuralism "available for a postmodern pragmatic anthropology" (Rajan 2002:36).

30. The examples are from Latour's *The Pasteurization of France* (1988), the italicized terms are the object-oriented protocols that now are widely used for many other examples.
31. They defined themselves in the 1980s as "new" in distinction to older Mertonian sociologies of science that were more concerned with the institutions and ideals of science (organized skepticism, universalism, disinterestedness, common ownership of discoveries), by investigating the practices of how scientific work is actually done.
32. Berger and Luckman's popular re-presentation in English of the German tradition of sociological phenomenology of Simmel, Scheler, Schutz, and others, titled *The Social Construction of Reality: A Treatise in the Sociology of Knowledge* (1966) provided an archaic ring to the anthropological ear for claims that 'social construction' is an innovation of the 1980s. Indeed, what is interestingly dissonant is the invocation, by SSK, of a German philosophical tradition of social analysis grounded in the debates over method in the late 19th century (Dilthey, Weber) while seemingly hostile to, or oblivious to, their Continental philosophical descendants (phenomenology, heremenutics) drawn on by anthropologists. It is as if the universe of SSK were constituted by philosophies of science grounded in British analytic philosophy, and its restricted interpretation of logical positivism.
33. Key terms of thought collectives have symbolic or magical properties as slogans that turn people into enemies or friends. Fleck's formulation highlights the affect of accusatory terms, "you evil positivist, postmodernist, relativist" and so on which often have little to do with the actual commitments of the accused. The so-called science wars of the 1990s are a good example. Deleuze's and Latour's formulations stress the more positive mechanisms; Fleck also includes the possible dysfunctional effects.
34. The most prominent exceptions, none of whom belong to this genealogy, but who converse in subversion, dialect or minor language translation with them are, on the one hand, German language based scholars (Hans-Jörg Rheinberger's interest in Derrida and Husserl; Friedrich Kittler's materialist structuralism; and Avital Ronell's interest in psychoanalytic theory); and on the other hand, the long-standing interest of medical anthropologists in the French traditions of phenomenology (Bergson on duration, Merleau-Ponty on embodiment, Canguilhem on the normal–pathological, Foucault on discursive effectivity, madness, subjectivation). These more pragmatist, phenomenological, psychosocial, and psychoanalytic approaches have long been in

conversation with, or have been tested and contested by, medical and other ethnographies of the production of epistemic objects, sociocultural assemblages and institutions, and explanatory systems: for example, Byron Good's *Medicine, Rationality, and Experience* (1994), Mary Jo DelVecchio Good's *American Medicine: The Quest for Competence* (1995), and the work of Arthur Kleinman (1988, 2006), engaging phenomenology on the one hand and narrative theory on the other; Allan Young (1995), Tanya Luhrman (2000), Margaret Lock (2002), Andrew Lakoff (2005), João Biehl (2005, 2007), and Good and colleagues (2007) engaging Lacanian topology, Foucaultian discipline, on the one hand, and science studies' "epistemic objects" on the other hand; Veena Das's work (2007) engaging Wittgenstein and Cavell on the one hand and violence and poisonous knowledge on the other; the list could be extended.

35. My notes taken at Weinberg's speech before the Fifth Annual Meetings of the National Association of Scholars, held at the Marriott Hotel, Cambridge, Massachusetts. November 1994, on the theme "Truth and Objectivity in the Natural Sciences, Social Sciences and the Humanities."

36. There is a deeper history of some scientists' visceral negative reaction to science studies, which has to do with earlier strata of political interference with science both from the left and the right of European politics, and the felt need to preserve a degree of autonomy for the "republic of science." Isabelle Stengers reminds that scientists loved (her word and emphasis) Kuhn's notion of paradigm shifts (1955), ignoring Fleck's sociology that inspired it, because it did not challenge their autonomy and because it flattered their sense of scientific discovery being able to break with or transcend past habits of thought (Stengers 2000:5). By contrast earlier Bolshevik and Nazi interference in science generated considerable debate. Nikolay Bukharin's defense of political guidance of scientific production within a planned economy in London at the 1931 Second International Congress on the History of Society and Technology was greeted with enthusiasm by J. D. Bernal and Joseph Needham but was vigorously opposed by Michael Polanyi both in organizing the Society for Freedom in Science and his 1962 essay "The Republic of Science." It is the "irrationalism" of Heidegger and the Nazis' effort to purge "Jewish science" that still informs Gerald Holton's (displaced but understandable) visceral distaste for anything called postmodern. These earlier political debates were sanitized and internalized in the history of science field by calling them respectively internalist and externalist histories.

37. Indeed, in his effort to dethrone Durkheimian sociology, and to locate Gabriel Tarde as the relevant ancestor to ANT, Latour claims that in Tarde's effort to find a solution to the bifurcation of nature into two vocabularies of agents and causes, Tarde came upon a unifying notion of "folding," the topological trope that Deleuze stresses in his Foucault (1986), the trope of subjectivation as a matter of folding forms and forces back on themselves (Latour 2001d). For a different spin on Tarde, see Maurizio Lazzarato's La political dell'evento (2004) cited by Terranova (2007:139–141). This is a Tarde tuned to a telemedia environment. The public is a dispersed crowd (or "deterritorialized socius") constituted as a public by "affective capture" through relays and feedback among a patchwork of Internet, television, and print news and advertising media. Unsettling of the regulative ideals of rational public sphere debate, these affective publics are regulated through ways of life rather than argument or belief, as in "keep shopping" (after 9/11) or 'we won't allow the suicide bombers to disrupt our way of life' (London, Israel). Intervention here occurs by controlling attention and memory, leveraged through hiring of public relations firms and through norms for news coverage.

38. By contrast, a text such as Peter Redfield's otherwise evocative book (2000), on the location of the European satellite launch site in French Guiana, as part of a tropical development syndrome continuous with the French penal colonies in the same area (decadence, unfulfilled promises of welfare for the locals), does not have such an interest, and he quite rightly refused to consider himself part of the anthropology of science and technology project. One learns little, if anything, aside from the geographical reasons for locating the launch site, about the building of satellites, rockets, their scientific payloads, or the training of the scientists or engineers.

39. A striking example is the work of Nathan Greenslit on how people on medications relate to a double sense of who they are in relation to the drugs that allow them to function, incorporating often quite sophisticated understandings of the workings of hormones, pharmaceuticals, and even their own enrollment in marketing seductions (Greenslit 2007).

40. Rapp's (1999) study of how families received amniocentesis indications of Down's Syndrome contradicted secular middle class assumptions that most people would chose to terminate the pregnancy; her data forcefully reminds the strong religious strain of those who reacted by preparing family support systems for a disabled child understanding the meaning of life to reside in the moral tests and trials provided by God and that had their own rewards. Sherin Hamdy has found something similar in the refusal of dialysis patients in Egypt to opt for kidney transplantation that would put family or others at risk (Hamdy 2006). Sanal's studies of an African-American kidney donor showed a rich religious meaning structure that allowed the donor to feel she had turned around her life as well as that of her brother; while on the other hand, patients in Turkey could feel social displacement and quite deep reworking of affiliational socialities. More profoundly were the challenges to belief systems of doctors, who attempted to use a ritual structure to redress the novel handling of corpses, and the competition between deeply held beliefs about organ networks being privatized or socialized. Fox and Swazey's studies involve heart transplant experiments and the tyranny of the gift that patients and donors felt, and how these feelings were regulated by rules of anonymity. Cohen shows how organ harvesting can exacerbate gender, class and caste inequalities. Petryna explores how global clinical trial organizations attempt to deal with different levels of medical care in different parts of the world, and how ethical criteria and justifications are invoked to rationalize nonuniversal procedures.
41. See Rabinow 1996, 1999, on venture capital biotech startups in the aftermath of the 1980 legal changes of the Bayh-Dole Act and the Chakravarty Supreme Court decision, and on patient groups raising funds and providing blood for research. Sunder Rajan's *Biocapitalism,* 2006, and Sunder Rajan and colleagues *Lively Capital* (in press), on novel relations between biotech startups, especially as many changed from producing molecules to producing genomic data, and pharmaceutical companies; between large-scale public consortia and private research companies; between government laboratories and pharmaceutical companies in India; and more generally between the promissory structures of capital investment in the life sciences and shorter term reorganizations and redirections.
42. I take the phrases "problematic of emergence" and "epistemologies of encounter" from Chris Kelty (2007). They participate in a family of resemblance with a tradition of concern with "emergent forms of life" (Fischer 2003), and cultural critique by epistemological juxtaposition (Marcus and Fischer 1986).
43. Building open access to communication networks requires overcoming regulatory, as well as technical and social challenges. All three tactics of low cost, open source, technology, guerilla expansion of user base and demand, and leverage from within the government are required. The struggle to get regulatory legislation that would cover the lowest bandwidth (or "third layer" of ICT) and make it available to the public will generate, not subtract, demand and users for the telecommunications industry. The first Internet gateway was at the University of Indonesia in 1993. Onno Purbo at ITB set up a used x286 computer, and a ham radio 2-m band to connect to the Aerospace Agency in Bogor. The system was 1.2 kilobytes per second, packet technology, radio network, an old Pentium 1 and 2 as server, all self-funded, built by ITB students. By 1995, they had upgraded the system a bit, but the army came and threatened Purbo with jail. The Director General of Telecommunications asked Purbo to move the frequency, which he did, in the process expanding coverage. Quickly there were too many people doing this for the police to control. It was, grins Purbo, a successful guerilla campaign. Meanwhile, the then-rector of ITB saw no need for the Internet and refused funding requests. Purbo says one needs three ingredients to win the fight for expanded access: power, money, or mass activity. It is the last that he uses for leverage. He paid for a telecom link and then began showing people how to put free telephony switches on top. For this he briefly went to jail, in the process generating more positive publicity both domestically and internationally. He resigned from ITB, arguing that he could reach only 200 students at a time there, but by doing his guerilla demonstrations, workshops, and participating in some 170 mailing lists he is now able to reach thousands. His "guerilla" activity is designed to create public pressure for the creation of legalized regulatory structures for the "third layer ICT." (The first layer is fixed line telecommunications, the second layer is cell phones, both controlled by companies, regulated

as utilities. It is illegal to operate without a license.) There are technical, social, and above all regulatory challenges. The effort, as his former colleagues at ITB say, is to create a third layer communication network that villagers, schools and communities can sustain themselves, creating content for their own needs, using low cost assemblies, open source technologies, and building infrastructures linked via standard protocols that a high school student can deploy. Technical problems include designing platforms assembled of low cost radio links, satellite links, and routers that can support voice transmission. Take a Chinese cooking wok ($4), attach a wireless USB ($24) that gives a range of 4–5 km, and with a few other cheap pieces you can have a Wokbolic assembly for $35, like a satellite dish. Social problems include how to do updating of 70,000 villages, using peer-to-peer technology, and how to create business models for rich, poor, and extremely poor villages. But the primary problem at the moment is regulatory. Self-assembly has been spreading, and there have been police raids of cyber cafés to take away computers. The government has agreed not to tax (license) 2.4 gigabyte equipment, but the fight now is to make it 5.6 gigabytes, and to remove the language in the regulatory agreement that still in principle requires all equipment to be licensed. It is a joke, Purbo says, to require the government to approve a wok-based piece of equipment. When his son's high school Internet collapsed, running a hundred computers on two slow DSL lines, he helped them set up their own mailman on a Linux server. While Purbo purses the strategy use base growth to pressure the government for regulatory reform, his former colleagues at ITB, are pursuing the technical problems and lobbying inside the system for changes with the regulators. One of these former colleagues, the former ITB Rector is now Minister of Technology and Research and is trying to manage the countervailing political and bureaucratic pressures from the government side. Based on my interviews with Onno Purbo, Kusmayanto Kadiman, Armein Langi, Budi Rahadjo and others September 2006.

44. Based on my interviews with Mansuri, Hessamaddin Arfaei, Cumrun Vafa, Yusuf Sobuti, and others in 2006 and 2007.

45. Based on my interviews with Arash and Kamran Alaee in 2006 and 2007, as well as reports by Broumand (1997), Ghods (2004), and Zargooshi (2001).

46. Kiki Papageorgiou at the Department of Anthropology, University of California, Irvine, is writing her dissertation on Sekem, and I am indebted to her work, presented at the American Anthropological Association Meetings 2006. Sekem's activities can accessed by googling their website.

47. From Al-Kharazmi as the father of algebra; the Kerela toddy tappers as informants to da Orta and von Reede's and thence Linnaeus's botanies; Chinese, Auryvedic, Galenic/Yunani and Ibn Sina (Avicenna)'s medicines; ibn Khaldun's sociology, Brahminic roots of Ramanujan's mathematical virtuosity; Jesuit contributions to Chinese mathematics; madrassa and yeshiva backgrounds to some scientists argumentative and calculative skills; Protestant roots of the purificatory preparations for demarcating, pursuing and verifying science (viz. Bacon and Popper in Ronell 2005; more generally Weber); colonial accounts of restricted access to scientific jobs, or postcolonial accounts of brain drain and dependency.

48. The Indian satellites were to be multifunctional: monsoon tracking, crop prediction, informational dissemination to farmers and villages, educational television. The program even had resident anthropologists to track the impact and provide feedback to the designers of programming. It also produced several prominent filmmakers, such as Ketan Mehta. A community science center set up nearby by physicist Vikram Sarabai, and his assistant, E. V. Chitnis (Director of the Center for Space Applications Research), provided hands-on laboratory equipment for after school experimentation and helped produce a group of now prominent scientists, such as the malaria biophysicist Chetan Chitnis (M.A. Rice University, Ph.D. Berkeley, postdoctorate NIH), now a Howard Hughes Medical Isntitute Investigator at the International Center for Genetic Engineering and Biotechnology in New Delhi. TIFR (Tata Institute for Fundamental Research) is a world-class research institute set up by the physicist Homi Bhahba, known for its units of physics, molecular biology (established by Oveid Sidhiqqi), and mathematics. (Based on my interviews with the Chitnis father and son, Sidhiqqi, and others at TIFR and ICGEB in the 1990s.)

49. C. K. Tseng, the father of modern seaweed biotechnologies in China, founder of China's Marine Biology Laboratory and other ocean science institutions, was educated at the University of Michigan, and spent the WWII years at the Scripps Institute of Oceanography (Neushul and Wang 2000). Tsien Hsue-shen, father of the Chinese missile program, got his start as a leading figure at CalTech and the Jet Propulsion Laboratory in Pasadena (Chang 1995). He trained briefly at MIT, but transferred to CalTech to work with Gottingen trained Theodore von Karman, who had consulted at Beijing's Tsing-Hua University, where MIT trained aeronautics professors sent Tsien to MIT.
50. B. J. Habibie rose to be a lead engineer and designer of the European Airbus before returning to Indonesia to head up an effort to build first an aeronautics industry, and then ships, trains and automobiles, as well as stimulate technological development more generally. The troubled story of these endeavors under the Suharto regime is a fascinating mix of transnational politics, domestic organization, and technical success. The Surabaya shipbuilding industry (tankers and grain transport) continues to be a success. Airplanes and a high-speed train were built, but the marketing of the former foundered on international certification issues, compounded by structural adjustment retrenchments. The automobile project foundered on Suharto family corruption demands. One often overlooked success was the reinvigoration of the Eijkman Institute for Molecular Biology under Melbourne-trained and professionalized biologist Sangkot Marzuki. Based on my interviews with Habibie, Marzuki, and others in September 2006, as well as at ITB and IBP (Institut Pertanian Bogor, the Bogor Agricultural University). On Habibie, see Amir 2005.
51. Nodal facilitators include: at ITB, Prof. Sulfikar Amir (2005); in Taipei: Prof. Wen-Hua Kuo (2005) and Prof. Fu Daiwie; at the National University of Singapore: Prof. Gregory Clancey (2006); at Sharif University: Prof. A. N. Maskhayekh; at the Institute of Philosophy: Prof. Shapour Etemad; in Bogota: Prof. Aleixis de Greiff. In India there is a variety of literature: Chouhan 1994, Nandy 1980, 1988; Visvanathan 1985, 1997; Raj 2000; Rajora 2002, Ramanna 1991; Sanal 2001, 2002; Shiva 2005, Shiva and Bhar 2001, Shiva, Bhar and Jafri 2002; the series of scientists biographies by Venkataraman 1992a, 1992b, 1994; the work on vaccine development by Veena Das and students at the Delhi School of Economics, and cosmopolitan or diasporic Indian interventions from Europe and the United States both associated with the Subaltern History collective and postcolonial studies (e.g., Chakrabarty 2002; Prakash 1999), and more specifically science studies (e.g., Abraham 1998; Jasanoff 1994; Sunder Rajan 2006).
52. Based on my interviews with Mansuri, Yusef Sobouti, Prenzan Premadi, and others in Iran and Indonesia, 2006–07.
53. The transformation of Infosys and Wipro, both based in Bangalore, are interesting stories of how companies were able to work up the value chain from back office work for foreign firms to body shopping to developing their own products. Nayaran Murthy, the founding director of Infoys was trained initially at an IIT (Kanpur), then at an Indian Institute of Management (IIM, Ahmedabad), where he was trained at the moment of transition from mainframes to personal computers by MIT-trained guru, J. G. Krishnayya, who himself went on to found a path-breaking public sector servicing company, Systems Research Institute (Pune, www.sripune.org) that helped computerize auditing tools, and specializes in GIS applications. Nayaran Murthy is somewhat unusual in having forgone advanced degree training abroad, but gained experience in large-scale projects by working for the Paris subway before joining SRI and then founding Infosys. Krishnaya and Murthy are generational hinges between older, state-sponsored and mainframe based computer services pioneered at TIFR and the National Center for Software Technology (NCST, led by S. Ramani, with postgraduate training at Carnegie-Mellon University). Often unnoticed in the enthusiastic accounts of the software industry in India is the long-standing role of Tata Consultancy Services, which trained much of the software labor force and continues to be a major player both domestically and internationally. (Based on my interviews with N. Murty, J. G. Krishnayya, S. Ramani, F. C. Kohli and others in the 1980s and 1990s.)

Editor's Note: From the outset, *Cultural Anthropology* has published articles that critically engage scientific and technological modes of thought, practices, artifacts, and infrastructures. See, for example, an early article of Michael M. J. Fischer, "Scientific Dialogue and Critical

Hermeneutics" (1988). In the mid-1990s, the journal published an article by Emily Martin "The Ethnography of Natural Selection in the 1990s" that is commented on by David Hess (1994), and also Gary Lee Downey and colleagues "Cyborg Anthropology" (1995). In 2001, Dan Siegel, editor of the journal at that time, published a special issue introduced by his piece, "Editor's Note: On Anthropology and/in/of Science" (2001).

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