

States of Knowledge

The co-production of
science and social order

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2 Ordering knowledge, ordering society

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Science in culture and politics

Science and technology account for many of the signature characteristics of contemporary societies: the uncertainty, unaccountability and speed that contribute, at the level of personal experience, to feelings of being perpetually off balance; the reduction of individuals to standard classifications that demarcate the normal from the deviant and authorize varieties of social control; the skepticism, alienation and distrust that threaten the legitimacy of public action; and the oscillation between visions of doom and visions of progress that destabilize the future. Both doing and being, whether in the high citadels of modernity or its distant outposts, play out in territories shaped by scientific and technological invention. Our methods of understanding and manipulating the world curve back and reorder our collective experience along unforeseen pathways, like the seemingly domesticated chlorofluorocarbons released from spray cans and air conditioners that silently ate away at the earth's stratospheric ozone layer. Just as environmental scientists are hard put to find on earth an ecological system that has not been affected by human activity, so it is difficult for social scientists to locate forms of human organization or behavior anywhere in the world whose structure and function have not been affected, to some extent, by science and technology.

Take culture, in particular, or more accurately cultures. Although science and technology are present everywhere, the rambunctious storyline of modernity refuses to conform to any singular narrative of enlightenment or progress. The familiar ingredients of modern life continually rearrange themselves in unpredicted patterns, creating rupture, violence and difference alongside the sense of increasing liberation, convergence and control. The terrorist attacks in the United States on 11 September 2001 acted out in brutal reality and on global television screens many contradictions that were already seething below the surface. On a clear, sparkling day in early fall, nineteen young Muslim militants hijacked four civilian aircraft and rammed them into the World Trade Center's twin towers in New York, the Pentagon in Washington, and a field outside Pittsburgh, Pennsylvania. This was suicidal violence on a previously unimagined scale. The pyres on which the hijackers immolated themselves killed more than 3,000 innocent people who had

left home for a normal day at work. The shockwaves broke America's late-twentieth-century dream of inviolability, and hastened the birth, some said, of a new empire dominated by American military might. US-led wars in Afghanistan and Iraq toppled regimes and fundamentally altered the legal and political order of the post-Cold War world.

Yet, at the threshold of a new millennium, this 11 September and its violent aftershocks only dramatized in horrific form much that was already known. Industrial societies, despite their many commonalities, articulate their needs and desires in different voices. Despite the ubiquity of CNN, Microsoft and the Coca-Cola can (Barber 1995) – and the global homogeneity they signal – the din of multivocality rises rapidly as one leaves the havens of the industrial West. Politicians and citizens in Washington, Paris, Tokyo and Baghdad have met the challenges and dislocations of the present with disparate resources and divergent criteria of what makes life worth living. The world is not a single place, and even “the West” accommodates technological innovations such as computers and genetically modified foods with divided expectations and multiple rationalities. Cultural specificity survives with astonishing resilience in the face of the leveling forces of modernity. Not only the sameness but also the diversity of contemporary cultures derive, it seems, from specific, contingent accommodations that societies make with their scientific and technological capabilities.

The dynamics of politics and power, like those of culture, seem impossible to tease apart from the broad currents of scientific and technological change. It is through systematic engagement with the natural world and the manufactured, physical environment that modern politics define and refine the meanings of citizenship and civic responsibility, the solidarities of nationhood and interest groups, the boundaries of the public and the private, the possibilities of freedom, and the necessity for control. What we know about the world is intimately linked to our sense of what we can do about it, as well as to the felt legitimacy of specific actors, instruments and courses of action. Whether power is conceived in classical terms, as the power of the hegemon to govern the subject, or in the terms most eloquently proposed by Michel Foucault, as a disciplining force dispersed throughout society and implemented by many kinds of institutions, science and technology are indispensable to the expression and exercise of power. Science and technology operate, in short, as *political agents*. It would not be utterly foolhardy to write the political history of the twentieth century in terms of its most salient technoscientific achievements: the discoveries of the atom and the bomb, the gene and its manipulation, radio communication, television, powered flight, computers, microcircuitry, and scientific medicine.

In what conceptual terms, then, should we discuss the relationships between the ordering of *nature* through knowledge and technology and the ordering of *society* through power and culture? How should we characterize the connections between the human capacity to produce facts and artifacts that reconfigure nature, and the equally human ability to produce devices that order or reorder society, such as laws, regulations, experts, bureaucracies, financial instruments, interest groups, political campaigns, media representations or professional ethics?

Does it any longer make sense for those concerned with the study of power to assume that scientific knowledge comes into being independent of political thought and action, or that social institutions passively rearrange themselves to meet technology's insistent demands? Established disciplinary languages fail us in grappling with these questions; disciplinary scholars find themselves at a loss for words, almost as if a Wall Street banker were asked to interpret a Balinese cock fight or a Bangladeshi rice farmer to comment on DNA typing in the O. J. Simpson murder trial. To fill this void, we draw in this book on several decades of detailed scholarship on the workings of science and technology within society. More specifically, we elaborate on the concept of *co-production*, which has recently gained ground in the emerging field of science and technology studies (S&TS).

In this chapter, I begin to make the case for co-production by first delineating the gap it seeks to fill between frames of analysis espoused by the traditional social sciences. This is followed by a review of the literature in science and technology studies that underwrites work in the co-productionist idiom. To clarify the analytic aims of this literature, I delineate two broad streams of thought – the constitutive and the interactional – that deal, respectively, with the emergence of new socio-technical formations and with conflicts within existing formations. The next section elaborates on the patterned pathways by which co-production occurs, identifying four major research programs that have developed around this theme. The chapter concludes by recapitulating the implications of the co-productionist idiom for future work in S&TS. In the interests of cross-disciplinary engagement, the chapter points throughout to connections between work in contemporary science studies and theoretically compatible work in other related disciplines.

A language for hybrids

The need for a generative discourse for discussing the role of science and technology in society is abundantly clear. What happens in science and technology today is interwoven with issues of meaning, values, and power in ways that demand sustained critical inquiry. Consider, for example, the transformation of a sheep named Dolly, born of a virgin mother in an obscure laboratory near Edinburgh, Scotland, into a universally recognized symbol¹ – of progress for some and moral transgression for others. Cloning was hardly the kind of event that could be counted on to set in motion the machinery of high politics. The scientific claims of the Edinburgh researchers had not been tested or replicated when they captured headlines round the world; the implications of the research remained distant and speculative (Wilmot *et al.* 1997). Dolly was a product of biomedical, not military, science. Her materialization posed no immediate threat to people's livelihood or security. Yet presidents and prime ministers reacted in haste to the news of Dolly's cloning, recognizing as if by some inarticulate sixth sense that this was an event for which politicians as well as scientists would be held accountable. Similarly, on 9 August 2001, a still unseasoned President George W. Bush devoted his first ever televised news conference to his government's policies

for research with embryonic stem cells. Notably, too, the rush to find the right frames within which to fit Dolly or stem cells – in science, politics, morality or law – led to results that were far from uniform across liberal democratic societies (Jasanoff forthcoming a).

Such complicated choreography is not uniquely associated with the life sciences. In little more than a decade, a formless entity called the internet, whose organization and governance remain a mystery to most of its users, became a player in countless contemporary social transactions. In exploring its possibilities, millions of people began to alter not only the architecture of the internet but also, in diverse ways, their own preconceptions of what it means to belong to social units such as the family, community, workplace, firm or nation. The sum of their interactions has changed the nature of commerce and capital, producing integration and disruption on global scales. Sometimes with a bang, as in the work of the Al-Qaeda terrorist network and its violent aftermath, and at other times in incremental whimpers, notions of ownership, privacy, security, nation and governance are all being transformed. In the computer age, it is increasingly difficult to pin down with certainty the places where politically salient events originate, let alone to determine who controls the levers of power. Similar fragmentation and dispersal of authority have also been noted by sociologists of risk. Not without cause has the German sociologist Ulrich Beck (1998) called the politics of risk “a form of organized irresponsibility” (see also Beck 1992).

To be sure, the idea that the gene or the computer chip can reshape society around its inbuilt logic has lost its cachet in the world of scholarship, even though determinist arguments still predominate in much popular writing about technological developments. Unlike Athena sprung full-grown from brow of Zeus, social and political arrangements for exploiting, resisting or quite simply accommodating technological change do not emerge, intact and fully formed, in response to innovation and discovery. Technology does not, when all is said and done, “drive history” (Smith and Marx 1994). Legal and political institutions lead, as much as they are led by, society’s investments in science and technology. The material and cultural resources with which human actors bring new natural phenomena into view, or seek to domesticate unfamiliar inventions, often exist before the “discovery” of the objects themselves. The design of technology is likewise seldom accidental; it reflects the imaginative faculties, cultural preferences and economic or political resources of their makers and users (Bijker 1997; Bijker *et al.* 1987). In engagements with the physical world, we are not mere spectators whose responses and destinies are ineluctably transformed by the growth of knowledge and the acquisition of novel technological capability. At the same time, when we tune into the rhythms of everyday life, even at times of exceptionally rapid technoscientific change (as arguably in the late twentieth century), we experience more often the steady hum of continuity than the sense of disequilibrium. In short, the ways in which we take note of new phenomena in the world are tied at all points – like the muscles on a skeleton or the springs on a cot frame – to the ways in which we have already chosen to live in it. Yet, astonishingly, most theoretical explorations of how social worlds evolve only imperfectly reflect

the complicated interplay of the cognitive, the institutional, the material and the normative dimensions of society.

That traditional disciplinary discourses fall short in this way should not be taken as a sign of lack of progress in understanding the intersections of science and technology with politics and culture. To the contrary, several decades of research in science and technology studies have done much to illuminate how orderings of nature and society reinforce each other, creating conditions of stability as well as change, and consolidating as well as diversifying the forms of social life. A compelling body of scholarship has demonstrated that science and technology can be fruitfully studied as social practices geared to the establishment of varied kinds of structure and authority (Biagioli 1999; Jasanoff *et al.* 1995; Pickering 1995; Clarke and Fujimura 1992; Bijker *et al.* 1987; Barnes and Edge 1982). So viewed, the workings of science and technology cease to be a thing apart from other forms of social activity, but are integrated instead as indispensable elements in the process of societal evolution. Science, made social in this way, can be compared and contrasted with other exercises in the production of power (Latour 1999; 1988a; 1987). Increasingly, the realities of human experience emerge as the joint achievements of scientific, technical and social enterprise: science and society, in a word, are *co-produced*, each underwriting the other’s existence.

But where does this insight lead political and social analysis? Does the idea of co-production represent anything more than the intuitively obvious point that ideas of nature, no less than ideas of society, are constructed by human endeavor – that both science and technology are fundamentally human achievements? If that were all, it would be cold comfort. A theoretical enterprise that seeks to explain why the world is ordered in certain ways has to promise more than the line from the popular children’s song, “Everything hangs together because it’s all one piece”. Does co-production as we have defined it in Chapter 1 yield better, more complete descriptions of natural and social phenomena than are to be found in more orthodox accounts? Can co-production serve the explanatory purposes that we have come to expect of theories in the social sciences? Can it provide normative guidance, or at least facilitate our critical interpretation of the diverse ways in which societies constitute, or reconstitute, themselves around changes in their apprehension of the natural world? Can the co-productionist approach ever predict?

Recent work in science and technology studies strongly suggests that these questions can be answered in the affirmative, although modestly, especially with regard to prediction, and with due regard for persistent disciplinary divisions within the field that have tended to obscure some of its most general insights. There has been a dearth of scholarship that integrates salient theoretical currents within S&TS, largely emanating from sociological, political and cultural studies of science, with its rich store of empirical findings, the latter deriving most importantly from the history of science and technology, but augmented lately by a growing body of work using disciplines ranging from anthropology to law. A relatively narrow focus on the particularities of scientific and technological production is also partly to blame.

Scientific biographies and studies of specific theories, artifacts or institutions have not always made explicit the connections between the mundane practices of science and those of politics and culture. Feminist theorists are an obvious exception (Haraway 1989; Keller 1985), and a handful of other authors have explicitly addressed state–science relations from an S&TS perspective (for example, Jasanoff 1992; 1990; Ezrahi 1990; Mukerji 1989; Shapin and Schaffer 1985). For the rest, research on science and technology has not sought to build systematic connections between the micro-worlds of scientific practice and the macro-categories of political and social thought. Sociology and political theory, for their part, have tended on the whole to leave science, and only slightly less so technology, out of their analytic programs – again with notable exceptions (Bourdieu 1980; Habermas 1975; Merton 1973). To date, the knowledge-making and knowledge-implementing faculties of human societies have received considerably less critical attention than such staple objects of social theory as race, class, gender, ideology, interests and power.

Among social theorists, the one who perhaps most consistently sought to bring together the analysis of knowledge and power is Michel Foucault (1971; 1972; 1973; 1979), whose work has exercised growing influence on research in S&TS. Foucault's imprint is particularly apparent in work, including contributions to this volume, that deals with classification, standardization, and the accrual of power by institutions that have the capacity to discipline people's bodies, minds and forms of life. His monumental legacy, however, is less well suited to exploring how diversity keeps reappearing and reasserting itself, even in the most entrenched institutions of modernity, such as expert bureaucracies. Some of the chapters in this volume address this problematic.

With the other contributors to this volume, I suggest that we have now arrived at a point at which we can usefully begin to pull together what has been learned in S&TS about the interpenetration of science and technology with cultural expressions and social authority. While it may be premature to propound anything so ambitious as a theory of co-production, it is not too soon to begin with more circumscribed steps. We can ask, in particular, what aspects of the role of science and technology in society may most appropriately be couched in the idiom of co-production: for instance, what sorts of scientific entities or technological arrangements can usefully be regarded as being co-produced with which elements of social order; what are the principal pathways by which such co-production occurs; how do processes of co-production relate to more orthodox accounts of technical or political change in S&TS and other disciplines; and what methods and approaches are best suited to investigating instances of co-production?

In addressing these questions, it is helpful to separate the relevant S&TS literature into two strands that have sought in disparate though closely connected ways to theorize the interplay of society, science and technology. We may call these, for ease of reference, the *constitutive* and the *interactional*. The former is primarily concerned with the ways in which stability is created and maintained, particularly for emergent phenomena, whether in a particular site where knowledge is made, such as a research laboratory, hospital or legal proceeding, or

around a novel technoscientific object, such as the human genome or a periodic table for chemicals. At the most basic level, the constitutive strain in S&TS seeks to account for how people perceive elements of nature and society, and how they go about relegating part of their experience and observation to a reality that is seen as immutable, set apart from politics and culture. This body of work is most closely related to metaphysical concerns in the philosophy of science, because one cannot discuss the constitution of nature or society without resolving questions about what it means to be natural or social, human or non-human. Co-productionist accounts, however, are not content simply to ask what *is*; they seek to understand how particular states of knowledge are arrived at and held in place, or abandoned.

The interactional approach, by contrast, is less overtly concerned with metaphysics and more so with epistemology – or less with what is and more with how we know about it (Hacking 1999: 169). This line of work takes for granted that, in most exercises of world-making, neither science nor society begins with a clean slate but operates always against the backdrop of an extant order, in which people already “know” in pragmatic terms what counts as nature or science and what as society or culture. Nonetheless, boundary conflicts about where these domains begin and end continually arise and call for resolution (Gieryn 1999). As well, the recognition of new phenomena often entails confrontation between competing epistemologies. Work in the interactional mode probes how human beings organize, and periodically reorganize, their ideas about reality under these circumstances. It seeks to elucidate the myriad mutual accommodations between social and scientific practices that occur within existing socio-technical dispensations during times of conflict and change. If constitutive analysis focuses in the main on the emergence of new facts, things and systems of thought, then the interactional strain concerns itself more with knowledge conflicts within worlds that have already been demarcated, for practical purposes, into the natural and the social.

Varieties of co-production

Since scientific knowledge first came to be seen as constituted by social practices (Collins 1985; Latour and Woolgar 1979; Bloor 1976; Kuhn 1962), S&TS researchers have realized that the fruits of their labors are at best imperfectly captured by the dictum that scientific knowledge is socially constructed. This formulation gives rise to two unresolvable problems, one theoretical and the other pragmatic. The first is that it confers a kind of causal primacy upon the “social” that careful work in S&TS, broadly conceived, has consistently denied (Knorr-Cetina 1999; Collins 1998; Pickering 1995; Woolgar 1988).² Constructivism does not imply that social reality is ontologically prior to natural reality, nor that social factors alone determine the workings of nature; yet the rubric “social construction” carries just such connotations (Hacking 1999). The second and more practical difficulty is that the discourse of social construction tends to inhibit the symmetrical probing of the constitutive elements of both society and science

that forms the essence of the S&TS research agenda. One or another aspect of the “social” – be it “interests”, “capital”, “gender”, “state” or “the market” – risks being black-boxed, treated as fundamental, granted agency, and so exempted from further analysis.³ The suspicion that social constructivists are arrogating to themselves an Archimedean point from which to deconstruct science has provoked criticism of S&TS as insufficiently reflexive (Woolgar 1988). It is also this reductionist reading of the “social” that has allowed defenders of the transcendental nature of science to rail at the idea of science as a social construct; in the so-called science wars of the 1990s, attackers of science studies frequently charged the field with misrepresenting scientific knowledge as “merely” social or political (Sokal and Bricmont 1998; Koertge 1998; Gross and Levitt 1994). Of course, no adequately social representation of science could ever be dismissed with the label “merely”.

With greater maturity, science studies as a field has moved to show that what counts as “social” about science is itself a subject of unsuspected depth and complexity. For example, early efforts to explain how controversies end, in both science and technology (Richards and Martin 1995; Nelkin 1992; Bijker *et al.* 1987; Barnes 1977), often represented closure as a negotiated sorting out of competing social interests. Such work assumed, along with mainstream scholarship in economics and political science, that society can be unproblematically conceptualized as composed of interest groups with clearly articulated (exogenous) positions and preferences. These interests, or stakes, were then invoked to explain the positions taken by different actors concerning knowledge claims and their technological embodiments. Newer work recognizes the inadequacy of interests as a primary explanatory category. Interests themselves have a social history: how they arise and are sustained are matters to be investigated, not taken for granted. The results of such investigation include, *inter alia*, a greatly increased concern with the standardization of scientific and social practices (Bowker and Star 1999), a sensitivity to the place of material agents in the production of stable knowledge (Galison 1996; 1987; Pickering 1995; 1992), a focus on the techniques of scientific representation (Hilgartner 2000; Lynch and Woolgar 1990), a growing appreciation of the influence of language (Dear 1995; 1991; Keller 1985), a preoccupation with the bases of trust in science (Irwin and Wynne 1994; Porter 1995; Shapin 1994), and heightened sensitivity to the ways in which knowledge achieves practical universality in widely divergent socio-political settings (Jasanoff and Wynne 1998; Jasanoff 1986).

Perhaps the most important by-product of all this inquiry is the recognition that the production of order in nature and society has to be discussed in an idiom that does not, even accidentally and without intent, give primacy to either. The term *co-production* reflects this self-conscious desire to avoid both social and technoscientific determinism in S&TS accounts of the world. The concept has by now acquired a respectable ancestry within the field, although there are varying schools of thought on exactly how to define and employ it. Barnes (1988) came close to a co-productionist position in talking about the nature of power; the same human capacities for learning, responding to and transmitting

knowledge, he noted, are responsible for the creation of natural and social order. His two orderings are more interactional than mutually constitutive in the sense implied by other observers of co-production, and the role of material objects in constituting order is left vague at best. By contrast, Daston (2000), introducing a collection of essays on the “coming into being” of scientific objects, calls attention to their ability not only to focus scientific inquiry but also to crystallize emergent and socially salient features of their cultural contexts. These objects, like people, have “biographies”; they are “not inert” but quite often changeable and “attain their heightened ontological status by producing results, implications, surprises, connections, manipulations, explanations, applications” (Daston 2000: 10). They are for all practical purposes not only scientific objects but also social objects, produced in indiscriminate acts of synthesis out of a society’s epistemological, esthetic and instrumental strivings. All this is quite consistent with the standpoint of co-production represented in this volume, but Daston’s commitment in the end is to the *history* of science’s objects of study; neither power nor culture is explicitly an issue in her account, although the categories of state and society figure in the contributions of some authors. The making of science is also *political*, we argue; indeed, a central claim of our collection is that there cannot be a proper history of scientific things independent of power and culture.

Pursuing this line of thought, some S&TS scholars see co-production as a process that is as foundational as constitution-making or state-making in political theory, because it responds to people’s deepest metaphysical concerns. It does so, in part, by continually reinscribing the boundary between the social and the natural, the world created by us and the world we imagine to exist beyond our control. “Science” and “politics” can then be treated as separate and distinct forms of activity rather than as strands of a single, tightly woven cultural enterprise through which human beings seek to make sense of their condition. Others working in a co-productionist vein are less concerned with metaphysics and more interested in the practical accommodation of new knowledge within existing forms of life. For them, there is nothing inherently problematic about seeing the world as organized, at any given moment, into clearly demarcated domains of “science” and “politics”. Ideas and objects are simply obliged to undergo a kind of parallel processing in order for problems to be solved in either domain: that is, nothing significant happens in science without concurrent adjustments in society, politics or culture; similarly, intransigent social problems seldom yield to resolution without changes in existing structures of knowledge. Fitting technology into this picture makes for further quandaries, since humanity’s material productions affect both what we know and how we behave. S&TS scholars have differed importantly in how they view the role of the material and the inanimate in constituting social order, and the degree of agency that they are prepared to grant to non-humans (Hacking 1999; Latour 1996; Collins and Yearley 1992; Callon and Latour 1992).

As we shall see in subsequent chapters, there is no univocal position on these matters in current work in the co-productionist idiom. Instead, the authors show from varied perspectives that the co-productionist idiom can shed light on the

constitution of varied social orders, such as international regimes, imperial or comparative politics, science and democracy, and the boundary between public and private property; equally, this approach can illuminate situated interactions between scientific and other forms of life, in settings ranging from laboratory conversations and patients' discourses to the courtroom. Similarly, the co-productionist approach can address the formation of widely varied elements of natural order: for example, climate change, human intelligence, endangered species or sugar cane propagation.

Constitutive co-production

For the constitutive tradition in co-productionist work, we turn first and foremost to Bruno Latour, who formally introduced the term in his influential essay-monograph, *We Have Never Been Modern* (Latour 1993). Here, he explicitly linked constructivist themes from S&TS with themes of political philosophy, repeatedly asserting that the nature-culture divide is a creation of human (or, more specifically, Western) ingenuity. It is the mechanism by which Western societies sort the multitudes of hybrid networks that constitute their cognitive and material existence into seemingly autonomous worlds of nature and culture. So basic is the resulting duality in "modern" thought that Latour regards it as a constitutional dispensation: it underwrites all other ways of grasping the world. An appealing aspect of this view is that it genuinely is about co-production – that is, it does not presuppose any *a priori* demarcations of the world before that world is worked upon by human imagination and labor: "But Society, as we now know, is no less constructed than Nature, since it is the dual result of one single stabilization process" (1993: 94). The analyst's task is to make visible the connections that co-production renders invisible, so that both "natural" objects, such as the cloned sheep Dolly or the ozone hole, and "social" objects, such as experts or governments, can be seen as linked together in *actor-networks* whose heterogeneous constituents criss-cross the constitutional divide.

Latour's take on co-production is more material and less idealistic than that of many Anglo-American scholars writing outside the Marxist tradition, including most adherents of the Edinburgh school of the sociology of scientific knowledge. In exposing the constructed character of the nature-culture boundary, Latour calls attention to the role of material objects as well as human institutions in assigning hybrids to one or the other of his two constitutional domains. His program grants agency to humans as well as non-humans, although mechanical agents in Latour's accounts (as contrasted, say, with biological ones like Pasteur's yeast) often seem to operate as surrogates for human actors, homunculi to whom humans have chosen to delegate some part of their own agency. Embroidering on these ideas over many years, Latour has made telling observations about the pervasive interdependence of the natural, the social and the material: thus "nature" is the result, not the cause, of solving social controversies (1987); the laboratory is a microcosm of larger aggregations of power (1988a); material objects and artifacts, such as door locks or

speed bumps ("sleeping policemen"), incorporate and effectuate social norms (1992); big social institutions, such as capitalism or markets, are built (paralleling Barnes 1988) by the same means that scientists use in making persuasive representations of nature (1990); and the essence of modernity lies in its dedication to "purifying" the hybrid networks of nature and culture (1993). Representation plays a key role in holding the networks together. Scientific representations, in particular, are products of multiple translations of form and meaning between the observer, the observed, and the means of observation across the network.

For Latour, the power and stability of actor-networks is largely a matter of size; in an oddly realist bow toward bigness, he observes that it takes more resources to put together an ozone-hole network than, let us say, one around a discredited scientific theory such as cold fusion or parapsychology. Correspondingly, it takes more resources to destabilize larger networks than smaller ones. Power is not uniformly distributed throughout a network, even though many local contestations ("trials of strength") may take place between particular contiguous elements within it while the structure is taking shape. Power tends to concentrate, rather, in "centers of calculation" (Latour 1990), which control the instrumentalities – printing presses, statistical formulas, maps, charts, and every manner of scientific "inscription device" (Latour 1987) – by which dominant perceptions of the world are rendered into conveniently portable representations.

While all this is exceptionally rich and provocative, Latour's networks exercise power while displaying curiously little of the moral and political conflicts that normally accompany the creation and maintenance of systems of governance. He has little to say, for instance, about why the organization of technological practices or the credibility of scientific claims varies across cultures; why some actor-networks remain contested and unstable for long periods while others settle quickly; why work at some nodes stabilizes a network more effectively than at others; or what role memories, beliefs, values and ideologies play in sustaining some representations of nature and the social world at the expense of others.⁴ Some later work in actor-network theory has gone further than Latour's in acknowledging the fluidity of meanings and ontologies across networks, but the very foregrounding of multiplicity in these stories stands in tension with conventional political analysis that deals with clearly distinguished haves and have-nots (Law 2002; Mol and Law 1994). Put differently, when actor-network theory confronts the nature of power, as it often does, it side-steps the very questions about people, institutions, ideas and preferences that are of greatest political concern. Who loses and who wins through the constitution of networks? How are benefits and burdens (re)distributed by or across them? How willing or unwilling are participants to change their behavior or beliefs because of their enrollment into networks? By downplaying such issues, actor-network theory's welcome attempt to reinvigorate the place of the non-human and the material in accounts of power entails substantial costs with respect to the treatment of human agency and human values.

Andrew Pickering, in *The Mangle of Practice* (1995) directly addresses the normative asymmetry between the human and the non-human. He sets out to rectify what he sees as a major flaw in the classical actor-network approach, observing that, when all is said and done, there are important differences between human minds and bodies and non-human agents such as the weather, television sets or particle accelerators. There are things that machines and devices can do that no thinkable combination of human actors could accomplish without technological enhancement. Similarly, there are things that human actors can do and machines (as yet) cannot, such as form intentions and goals or exercise normative judgments, within the constraints of a world partially fixed or predisciplined by existing cultural commitments. The two kinds of actors nevertheless depend on one another at every phase of scientific practice – and, Pickering argues, also in cultural practices more broadly. Accordingly, what should be posited between human and material agents, he says, is not an exact equivalence, as for instance in the case of Latour's speed bumps and real traffic policemen, but rather *parallels* in their forms of action and an *intertwining* in their constitution of each other (1995: 15).

Speaking very much in a co-productionist idiom, Pickering encapsulates his ontological argument as follows: "The world makes us in one and the same process as we make the world" (1995: 26). The "world" that is the subject of this sentence is not the ultimate reality to which philosophical realists pay homage, but rather any of the many possible worlds that can be constructed through the dialectical interplay of human and non-human agencies (see Hacking 1999: 68–74 for a critique of this account). To spell out in more detail the mechanics of this process of co-production, or as he calls it "interactive stabilization", Pickering introduces the metaphor of the "mangle", a now obsolete machine designed for wringing the water out of wet washing. Scientific work, he says, can be thought of as feeding into the mangle a combination of human goals and practices and material potentialities. What comes out at the other end is a somewhat unpredictable transformation of both inputs, reconfigured into a newly stabilized field of action for further "dances of agency" between humans and machines.

Astute as Pickering is in observing the real-time interplay of human and mechanical agency in scientific practice, the notion of the mangle disconcertingly undercuts the very ideas of human intentionality that he wants to resurrect. There is, to begin with, an immovable, physical obduracy about the concept of the mangle. What is its own ontological status? Is this strange device part of the world it acts on or is it alone exempted from the flurry of actions, both human and material, that constitute the worlds we know? If it acts autonomously, whence does it derive its godlike imperviousness to the contingencies of world-making? Is the mangle's operation unpredictable because, in another guise, it is simply the realist's world lurking beyond the analyst's field of vision, ready to bite back upon human curiosity in ways that our comprehension cannot, as yet, absorb? And how thoroughgoing anyway is the unpredictability of mangling? Pickering acknowledges, after all, that "culture" has something to say about the

possibilities that confront the scientific entrepreneur, that all ways forward are never equally open, and that the worlds we have already constructed loop back on our efforts to construct new ones (Hacking 1999). Is there nothing, then, that we can usefully generalize about these constraints?

To pursue these questions further, we may usefully contrast Latour's and Pickering's views with those of authors from neighboring areas of philosophy and political theory. One informative contrast is with Philip Kitcher, the philosopher of biology, who also deals with the social nature of science in his monograph, *Science, Truth, and Democracy* (Kitcher 2001). Like Pickering, Kitcher is prepared to grant that science reveals, through human enterprise, only some of the many possible realities that nature in principle holds in store. The actual paths of discovery, according to Kitcher, follow socially ordained "significance graphs" that lead investigators to pursue some lines of inquiry in preference to others. Unlike Pickering's mangle, though, Kitcher's significance graphs do make room for human agency, but as I have suggested elsewhere (Jasanoff forthcoming b), Kitcher's account suffers from inattention to the role of power, resource imbalances and global inequality in privileging some significance judgments over others.

A second illuminating contrast comes from setting actor-network theory beside the work of two political scientists, Benedict Anderson and James C. Scott, who have also written influentially about the role of representational practices in constituting political power. For these authors, however, the power of representation lies not so much in the resources invested in creating them (though these are not irrelevant) as in the resources used to disseminate them, so that they alter the behavior or command the belief of masses of sentient human actors. If Latour and Pickering focus primarily on the production end of representing the world, Anderson and Scott are concerned as much or more with reception: in their case, the uptake of the results of such representations by powerful, and for Scott (1985) also powerless, agents in society. In particular, both political analysts are interested in the resistances that arise when particular grand representations of reality are employed to win the allegiance of large aggregates of people. The ensuing struggles of belief render their work quite explicitly political.

In *Imagined Communities*, his acclaimed account of the rise of the modern nation-state, Anderson (1991) broke with the standard definition of the nation-state as an autonomous entity wielding sovereign rights over a geographically bounded territory and the citizens inhabiting it. Concerned with the phenomenon of *nationhood*, he turned an anthropologist's eye on what makes people believe that they belong to something so nebulous and ill defined as a nation. From this starting point, Anderson defined the nation simply as "an imagined political community – and imagined as both inherently limited and sovereign" (1991: 6). By emphasizing the citizen's imagination, Anderson underscored the reciprocity of nation-making. A state may be, or may become, little more than an empty shell, though possibly one with brutal and oppressive instruments at its command, unless its citizens are willing to invest it with their own

dreams of shared identity. Mere accumulation of the hard indices of power – guns, laws, armies, revenues – may not be sufficient to build or maintain a robust dominion unless the state also has the means to exert a continuous, centripetal pull on its citizens' imaginations. The unexpected dissolution of the Soviet Union and of former Yugoslavia in the 1990s, the sudden crumbling of Afghanistan's Taliban regime under US bombardment in 2001, and the collapse of Saddam Hussein's Iraqi regime in 2003, again under US attack, can all be seen in this light as massive breakdowns in the capacity of those states to hold on to just such loyalties of the imagination.

In Anderson's account, nation-making crucially depends on deploying persuasive representations of the symbols that signify nationhood. The instrumentalities, or technologies, that figure most prominently for him are those that have the power to discipline people's imaginations by making them receptive to shared conceptions of nationalism. Anderson particularly emphasizes the role of print capitalism. National newspapers were among the earliest of his instrumental devices, simultaneously disseminating the same communal stories to every part of a country and so weaving together their readers in an invisible web of common narrative experience. Other instruments for standardizing national identities include, as Anderson specifies in later editions of his book, the map, the museum and the census (he might, after 2001, have dwelt longer on national flags). With their aid, even so culturally and spatially disjointed a state as Indonesia was able to create in its citizens' minds the sense of being Indonesian, of belonging to a politically integrated community. Any nation so conceived can certainly be seen, in S&TS terms, as a network that is partly held together by circulating technologies of representation and communication. But the durability of this network depends on more than the sum total of its variously functioning parts. A successful nation has to be able to produce the *idea* of nationhood as an emergent, intersubjective property; without this connection of belief, it remains a hollow construct, ruling without assent, and hence unstably.

James Scott (1998), like Latour, is specifically concerned with the texture of modernity, and his state, like Anderson's nation and Latour's science, wields power by making authoritative representations. In *Seeing like a State*, Scott describes how the modern planning state not only conceived of the world in certain recurrent, oversimplified categories, but also imposed its ways of seeing on people's lives. The name of the game was to bind citizens' whole existence, not just their imaginations, to the service of the state's grid-like vision. Through chilling accounts of such disastrous initiatives as scientific forestry in Europe, city planning in Brazil, collective farming in Russia, and villagization in Tanzania, Scott relates how various "high modernist" planners first created idealized, stripped-down images of social order and then ruthlessly redesigned millions of lives to match their reductive visions. The purpose of these grand plans was to make citizens and their economic productions more "legible", that is easier to count, survey, order, exploit and control. Small-scale, diversified, shifting or densely settled patterns of human life were eliminated in favor of large collectives, rigidly disciplined spaces, rectilinear orderings of dwellings, croplands and

forests. Like Cinderella's stepsisters mutilating their feet to satisfy the glass slipper's cruel dictates of beauty, Scott's planners cropped and purged their citizenry to meet the demands of legibility and centralized control.

These immense feats of natural and social engineering were driven, in Scott's view, as much by an esthetic predilection for clean, transparently governable spaces as by the planners' thirst for domination. He thus adds a normative and cultural element to the quest for power that one vainly looks for in actor-network theory. Moreover, if size alone conferred power on networks, or upon their centers of calculation, then Scott's planners should have been quintessentially powerful. The standardized units and measures that they created, and often forcibly imposed, subjugated vast populations to their templates of control. Yet most of these utopian ventures ultimately failed. Even their temporary successes must be attributed, Scott suggests, to the shadow politics of subversion and resistance played out in and around the peripheries of the governing vision. Squeezed out of planners' designs, "real" life found ways of resurfacing in the unwritten adaptations and accommodations of the powerless. When asked to draw a picture of "home", nine-year-old children living in Brasília's soulless superquadra did not draw "an apartment building of any kind. All drew, instead, a traditional freestanding house with windows, a central door, and a pitched roof" (Scott 1998: 127).⁵ More to the point – and playing out a script that Scott (1985) also detailed in his earlier classic study, *Weapons of the Weak* – an entire unplanned Brasília grew up side-by-side with the planned one in order to accommodate the construction workers and their families, illicit and invisible citizens, who had not been provided for in the monumental center that housed the city's bureaucratic elite. In the end neither half of the real Brasília, starkly segregated by wealth and class, conformed to the animating vision of the ideal, modern city that had prompted their joint creation.

Scott's notion of legibility rings changes upon the theme of standardization which many postwar social theorists have identified as perhaps *the* constitutive feature of modernity (Bauman 1991; Foucault 1979). Concerned as he is with measurement, Scott explicitly acknowledges the resonances between his work and that of well known S&TS scholars such as Ian Hacking (1990) and Theodore Porter (1995), who have also called attention to the simplifying moves that are needed to convert the messy realities of people's personal attributes and behaviors into the objective, tractable language of numbers. More recently, he might have included, too, Bowker and Star's (1999) study of classification practices in large social service organizations. But there are two dimensions to Scott's argument that render his work at once more and less compelling than similar studies in the social history of statistics and enumeration. On the one hand, Scott emphasizes the inequality of means between the state and those it wishes to render legible. Not every actor can see "like a state" because the wherewithal to impose such simplifying order on complex masses of humanity lies, for better or worse, outside the competence of most social actors. On the other hand, Scott's monolithic formation of legibility, modernity and the state lacks the nuance and situatedness that characterize the best S&TS work on the ambiguities and discontents of

modernity. Legibility, after all, has not been the exclusive prerogative of modernity, as is well illustrated by the highly legible caste systems of ancient India, medieval Europe or feudal Japan (Benedict 1989).⁶ Institutions other than the state, such as Foucault's clinics and schools as well as his prisons, and still more recently commercial institutions such as credit card companies and internet marketers, also have the power to create new ways of "reading" people;⁷ and these forms of power are diffused through society by micro-processes of clinical observation and diagnosis rather than imposed from above by the mailed hand of the state (also see Bowker and Star 1999). Modernity itself, finally, cannot be taken as a blanket state of affairs, a social *a priori* that is not itself embedded in the shifting sands of history. As historians of science have shown, even the objectivity of representation that Scott and others see as a defining achievement of modernity comes in different flavors at different times and in different socio-cultural settings (Daston and Galison 1992; Porter 1992).

I have suggested thus far that there are important family resemblances between the actor-network approach to thinking about power in constitutive, co-productionist terms and newer approaches in state theory, such as Anderson's and Scott's, that focus on the role of representation, visualization and standardization in constructing political regimes. Juxtaposing the two lines of analysis, however, reveals problems in each. Generally, S&TS work has been less successful than political science in finding places for human beliefs and imagination, and in accounting for significant economic, technological and social disparities in the practices of world-making; nor has science studies paid much attention to what happens when particular epistemic and material constructions of the world circulate through societies configured by very different historical and material constraints. Work in political science, by the same token, has tended to black-box or take for granted the primary units of political analysis, such as "high modernity" or the "state", and has paid insufficient heed to the interplay of social with natural order. Can the co-productionist idiom do better? Before returning to this question, we must consider the second major tributary in the literature on co-production – the interactional strand that takes as its primary object of study the accommodations between scientific and other forms of social life at moments of manifest conflict and change.

Interactions of science and politics

Just as constitutive co-production usefully takes the metaphysics of Latour and the French school of actor-network theory as its point of departure, so the interactionist strand can be grounded, to start with, in the epistemologically oriented Edinburgh school of sociology of scientific knowledge. In *Leviathan and the Air Pump* (1985), their important study of science and politics in early modern England, Steven Shapin and Simon Schaffer undertook to explain an intriguing – and, for us, instructive – historical puzzle. Casting back to two of Restoration England's most influential thinkers, Thomas Hobbes and Robert Boyle, Shapin and Schaffer observed that the pursuits of these two intellectual giants were not

so easily classified in their own time as they have since become. Hobbes today serves as a staple of political theory, whereas Boyle retains his status as one of the founders of modern science. In the seventeenth century, however, both men navigated rather more freely on either side of the science–society boundary, Hobbes pronouncing on natural philosophy and Boyle on politics and power. Where did the divisions come from that later put each man so unambiguously in his place? And does the historical record say anything more general about the origins of the separation between the natural and the social that citizens of the modern world tend to take for granted?

The disputes between Hobbes and Boyle centered in the first instance on the credibility of the latter's experimental method. Hobbes played the skeptic to Boyle's famous air pump experiments, arguing, much in the deconstructive style of a contemporary sociologist of scientific knowledge, that the experimenter's own authority was crucial to establishing the authority of the experiment (Collins 1985). Boyle, as Shapin and Schaffer ingeniously demonstrate, invented a complex technology of validation – including a depersonalized rhetoric of objectivity – to persuade critics like Hobbes of the reliability of his experimental knowledge. The heart of *Leviathan's* co-productionist argument, however, has to do with the relationship of the debate between these two men and the wider political conflicts of the disordered era in which that debate was taking place. At stake, Shapin and Schaffer propose, was not only the nature of the knowledge that would be deemed reliable in the post-Restoration polity, but also, simultaneously, questions about what kinds of people would be allowed to lay claim to power through the trustworthiness of their knowledge. These observations underwrite what is for our purposes the authors' most significant conclusion: "Solutions to the problem of knowledge are solutions to the problem of social order. That is why the materials in this book are contributions to political history as well as to the history of science" (Shapin and Schaffer 1985: 332).

In this view of co-production, human beings seeking to ascertain facts about the natural world are confronted, necessarily and perpetually, by problems of social authority and credibility. Whose testimony should be trusted, and on what basis, become central issues for people seeking reliable information about the state of a world in which all the relevant facts can never be at any single person's fingertips. At times of significant change, such as those we tend to call "scientific revolutions" (Shapin 1996; Kuhn 1962), it may not be possible to address questions of the facticity and credibility of knowledge claims without, in effect, redrafting the rules of social order pertaining to the trustworthiness and authority of individuals and institutions (witness the new technologies of persuasion created by Boyle and his fellow experimentalists to convince skeptics and absent colleagues). Only by solving social problems in this way can satisfactory warrants be produced for radically new orderings of nature. Doing science merges, in other words, into doing politics. Shapin and Schaffer concluded that there are, in practice, three senses in which

the history of science occupies the same terrain as the history of politics. First, scientific practitioners have created, selected, and maintained a polity within which they operate and make their intellectual product; second, the intellectual product made within that polity has become an element in political activity in that state; third, there is a conditional relationship between the nature of the polity occupied by scientific intellectuals and the nature of the wider polity.

(1985: 332)

Although this statement assumes the separate existence of science and politics, the authors are careful not to posit unidirectional causal arrows running from one domain to the other. Natural order does not shape social order, nor vice-versa. Rather, there is, as Pickering also implies, a necessary *parallelism* between goings on in these two spheres of human activity.

Each of the three “senses” of co-production identified by Shapin and Schaffer has respectable resonances elsewhere in writings about the politics of science and technology, and some comparisons with those works let us recognize as well how radically co-productionist ideas and related work in S&TS break with earlier traditions. So, we find in two classic mid-century articles by Michael Polanyi (1962) and Robert K. Merton (1973 [1942]) – on the republic of science and the normative structure of science, respectively – the notion of science as a model polity.⁸ Both men saw scientific activity as governed by norms, such as disinterestedness for Merton and the absence of hierarchical authority for Polanyi, that were well adapted to serve the needs of open, democratic discourse. Shapin and Schaffer question the taken-for-granted character of such norms, suggesting that experimental science’s claims of reliability and truth had to be sustained through elaborate and carefully designed social practices (see also Shapin 1994). (Ironically, they are less skeptical toward the political order of Restoration England, which they largely take for granted, rather than seeing it too as contingent, contested and stabilized through practice.) Other work in the sociology of scientific knowledge, such as Collins (1985) on “core sets” and Gieryn (1999) on “boundary work”, has amplified these ideas, underlining the role of mundane practices in stabilizing and delimiting the politics of science and in defining scientists’ ultimate forms of life. The import of such studies has been to challenge the assumption of science as an autonomous sphere whose norms are constituted independently of other forms of social activity. Rather, the resolution of any significantly new problems in science is seen as requiring situated and specific (re)structurings of social order, without which scientific authority itself would be put in jeopardy. Observers of the changing norms of scientific practice at the end of the twentieth century have reached similar conclusions about our own period of transformation (Nowotny *et al.* 2001; Gibbons *et al.* 1994).

The idea of intellectual product becoming “an element in political activity”, the second kind of interaction between science and society proposed by Shapin and Schaffer, is reminiscent of work on the politics of technology by David

Noble (1984) and Langdon Winner (1986). Winner, in particular, argued for the “inherently political” nature of technology in somewhat the same language that Shapin and Schaffer used for science:

[T]here are two basic ways of stating the case. One version claims that the adoption of a given technical system actually requires the creation and maintenance of a particular set of social conditions as the operating environment of that system....A second, somewhat weaker version of the argument holds that a given kind of technology is strongly compatible with, but does not strictly require, social and political relationships of a particular stripe.

(1986: 32)

Technology in these terms is a “solution” to political order in the sense that it sustains particular structures of established power, as in Winner’s heuristically useful (though historically problematic⁹) example of highway overpasses in New York designed purposefully too low to allow buses carrying the urban poor to travel into wealthy suburbs. Similarly, in his account of the adoption of numerical control in the machine tool industry, Noble argued that the new technology enabled shop-floor managers to deskill and thus maintain control over potentially fractious workers. Complex technological systems such as nuclear power may embody or necessitate opaque and illiberal forms of political organization, a theme advanced by Winner and echoed by Richard Sclove (1995) in his call for the democratization of technology. While all of these authors are sensitive to the interpenetration of material and social structures, they deviate from the co-productionist thrust in S&TS by taking for granted certain social “facts”, such as the necessity of the alliance between economic and political power and the ordering of society according to well defined interests. Hence, in their writing, social formations such as capital or class are held to be off limits for analysis and not available for reconfiguration in new attempts to solve “problems of knowledge”. Instead, like James Scott’s all-powerful state, they are seen as repeatedly reinscribing themselves in the products of technoscience: highways, power plants and machine tools, for example.

Even the hegemonic forces of capital or colonialism, however, do not maintain themselves static and unchanging for all time. William Storey (1997: 141–149) offers an elegant illustration in his history of colonial-era sugar manufacturing in Mauritius. During the 1920s and 1930s, small planters on the island established a thriving market in Uba canes, a high-yielding variety cultivated by local growers. The canes were profitable at first because sugar factories paid the planters for them by weight rather than yield. The factory owners did not especially care for this arrangement because the Uba variety yielded less sucrose than the standard varieties grown by large plantation owners. Factories continued to accept the canes, however, until low sugar prices and the depression of the 1930s caused them to retreat from this policy. An announcement in 1937 that the sugar factories would pay 15 per cent less for Uba canes caused the small planters to

riot and brought the Mauritian economy to a standstill. The British government solved the problem by providing the rioters with new, hybrid canes, which yielded so well that they pre-empted the dispute between planters and factory owners. A radical problem of social order was resolved in this way by changing the accompanying natural order: the switch from “local” Uba to “colonist” or “metropolitan” hybrid canes, and associated changes in the distribution of the knowledge of sugar cane cultivation and in tax policies. The disorder of the riots disclosed, albeit fleetingly, how the very composition of the dominant cane varieties embodied complex accommodations between nature and society. The Uba cane and its hybrid successor stabilized – indeed naturalized – different regimes of colonial knowledge and power, whose rules they at once incorporated and made invisible.¹⁰

Finally, with respect to possible “conditional relationships” between science and politics – Shapin and Schaffer’s third site of interaction – both Polanyi (1962) and more recently Yaron Ezrahi (1990) have argued for the strong case that modern science provides the template for a particular form of politics: liberal democracy. Polanyi’s vision, however, was anything but co-productionist. His highly idealized republic of science developed its own rules of the game essentially uncontaminated by power or politics; these rules, Polanyi suggested, are suited to democratic governance because they deny any authority except that which is constituted from below by the self-critical and equally positioned “peers” of the scientific polity.

Ezrahi, by contrast, builds sophisticatedly on Shapin and Schaffer’s observations about Boyle’s construction of an experimental space whose credibility could be vouched for by distant virtual witnesses. Ezrahi found in the rise of experimental science and the decay of the alchemist’s or the absolute monarch’s privileged vision a historical antecedent for the creation of authority in democratic polities. Politics after the scientific revolution became, he argues, an extended “experimental space”, in which the modern, liberal state could use science and technology for instrumental ends to gain the assent of its witnessing (“attestive”) publics. Unlike Polanyi’s curiously unsocial republic of virtue, Ezrahi’s democracy is constituted through continual pragmatic adjustments between the state and its citizens: the state exercises power only by maintaining a commitment to transparency, while citizens accept rule by the few only because the state’s instrumental actions are continually visible, and so available for public review. Importantly, Ezrahi’s account of the rise of democracy focuses not only on the state’s instrumental strategies, but also on the emergence of a particular kind of knowledgeable citizen, the liberal individual who is capable of attesting, as an informed and reasoning witness, to the legitimacy of the state’s technological actions.¹¹

To underline the co-productionist well-springs of Ezrahi’s thinking about science and the state, it is helpful to contrast his views with Chandra Mukerji’s (1989) interesting ethnographic study of a community of oceanographers who owe their existence to state support and funding. Mukerji describes her scientists as a “reserve labor force” for the state, which shores up its authority and serves

its eventual security needs by sponsoring their research. The scientists enjoy the illusion of autonomy, while the state produces knowledge to suit its own purposes. In this world, the instrumental state and the science it sponsors are separated by an impermeable wall (it is methodologically telling, for example, that Mukerji does not interview her “state” representatives); the images the scientists produce of the world appear to be of no concern to the state, let alone to loop back in any way on the state’s relationship with its citizens. As Noble and Winner black-box the power of capital, so Mukerji takes the power of the state as primary. It is not problematized nor seen to be in continual need of relegitimation with the aid of science and technology, as in Ezrahi’s or Storey’s accounts of democratic and colonial political orders, respectively.

A more contingent set of “conditional relationships” can be observed in the case of the human and social sciences, whose growth and importance have been closely linked to the rise of the modern managerial state. Foucault’s descriptions of the normalization of mental illness and sexuality provide the most influential point of departure for this line of research. The medicalization of insanity (Foucault 1973), the definitions of normal and abnormal sexuality (Foucault 1978), the rise of statistics (Porter 1995; Hacking 1990; Daston 1988), the standardization of intelligence (Carson 1993), the creation of “legible” cadastral maps (Scott 1998), and the sorting activities of health and welfare organizations (Bowker and Star 1999) are among the examples of the social sciences emerging to serve – and shape – the modern state’s desire for specific forms of order, control and reassurance.

This literature displays a certain ambivalence about the ways in which the construction of social knowledge relates to the production and exercise of power. Who is empowered through knowledge, and to what ends? Foucault’s early writings present a compelling and pessimistic vision of social classification serving the state’s need for order and surveillance, leaving citizens more or less powerless to resist. Foucault’s state looks through a one-way mirror; his model is Jeremy Bentham’s Panopticon, the ingenious circular penal structure in which the centrally positioned guard can look out at all the inmates, but never be seen in return. This is a far cry from Ezrahi’s transparent and vulnerable liberal democratic state, which is destined always to deploy science and technology in full view of its citizens, and therefore must continually construct demonstrations – in war and peace – to persuade citizens that it is acting for their collective benefit.

Helga Nowotny (1990) and others (Wagner *et al.* 1991) also suggest a relatively benign reason for the growth of the social sciences in modernity: one of the modern state’s necessities is to provide reassurance to citizens against the uncertainties of poverty, crime, unemployment, and more recently environmental and technological risk. Of course, the risks themselves are historically and culturally contingent, and the analytic tools that any society musters for their management reflect a preoccupation with the collective fears or problems that arise in particular times and places. Hacking (1999; 1995; 1992) persuasively describes how the American legal and policy processes created the new “social kinds” of child abuse and “recovered memory” in response to specific cultural anxieties of the

1980s – and, in the process, went about generating “objective” evidence of these phenomena on a scale unparalleled in other Western societies. Other developments in the social sciences that have responded to public demands for reducing uncertainty include mortality tables, actuarial systems, risk assessment, and varied indicators of socio-economic performance (Daston 1988; Porter 1995; Jasanoff 1992; 1986; Hacking 1990; Wynne 1989; Daston 2000; among others). With these we could also range an emerging body of environmental sciences – with names like sustainability science, vulnerability science, integrated assessment – which display similar properties but have not yet been studied in detail. These classifying instruments often have the effect of disciplining people in a Foucauldian sense, but in subjugating prevalent uncertainties, they also create a promise of control, and thus in some instances liberate people to act more freely; whether advisedly so or not is a very different question.

A related strand of the co-production literature deals with notions of objectivity, reliability and expertise that apply not only to the legitimation of science and technology, but also to the constitution of democratically accountable political regimes. The very idea of objectivity implies the existence of a shared reality against which free men and women can test the performance of their governmental representatives. Objectivity, of course, has been an important theme in the philosophy of knowledge (Rorty 1991), but S&TS research has devoted more punctilious attention to this notion’s social history and cultural specificity. How objectivity is understood and institutionally embedded in a given political system has enormous implications for the sponsorship of science by the state: it influences the kinds of work that are deemed appropriate for public funding (projects that provoked spirited debates about science’s objectivity and neutrality at the turn of the twenty-first century include cloning and stem cell research, the Human Genome Project, climate modeling, DNA typing, and sampling techniques for birds, fish, biodiversity, and racial groups), as well as the organization of scientific research. For example, in sponsoring closer university–industry relations so as to speed technology transfer, states had to take note of, and guard against, charges of conflict of interest (Guston 2001). In turn, concepts of objectivity and reliability affect the uptake of science and technology by state institutions: how the results of research are construed in public domains (for example, as persuasive, biased, irrelevant or inconclusive); how they are factored into the framing and “solution” of public problems; how new technical discourses are constructed to legitimate policy; and so forth. Well entrenched habits of skepticism in American politics, for example, have been linked to a recurrent, utopian search for neutral approaches to conflict resolution, framed by objective, quantitative decisionmaking techniques, such as vulnerability assessment, risk assessment and cost-benefit analysis (Jasanoff 1995; 1986; see also Porter 1995).

Much of the work reviewed thus far concerns itself directly and centrally with relationships between science, technology and governmental power, or its close correlate, economic power – that is, the power of rulers over the ruled. Feminist and cultural studies of science, by contrast, have dealt with the intersections of

knowledge, technology and power without necessarily implicating the authority of the state. Thus, in her pathbreaking essays on gender and science, Evelyn Fox Keller (1985) set out to show how concepts central to the practice of science, such as objectivity, came to be gendered as “masculine” through centuries of rhetorical usage. In a passage that is especially germane to this discussion, Keller argued that the concept of “laws of nature” is “indelibly marked by its political origins” (1985: 131). Once cast as a search for law, scientific research orients itself toward monocausal, hierarchical explanations in which nature is controlled by deterministic forces that dominate lower-order variables much in the manner of an authoritarian, centralized state ruling its subservient citizens. Such an understanding of nature, in Keller’s view, is anything but gender-neutral. She suggests that “order” rather than “law” would provide a richer (and presumably less masculine) framework for scientific inquiry, because the former term “wider than law, and free from its coercive, hierarchical, and centralizing implications, has the potential to expand our conception of science” (1985: 132).

Keller restricts herself to speaking about natural order, but her argument could easily be extended to show, as the authors in this collection do, that the expansive notion of “order” provides an equally hospitable idiom for enlarging on the interactive, mutually constitutive relations between nature and society. This is a route that Keller herself leaves mostly unexplored; for instance, while she illuminatingly tracks the influence of gender in scientific language and praxis, she does not, in a fully symmetrical, co-productionist move, consider the construction of “gender” itself as a powerful ordering category within the varied knowledge cultures of modernity. An analysis of the cognitive, social, symbolic and even material resources with which the concept of gender is stabilized, would have told us a lot about what is at stake in the politics of femaleness in various socio-cultural settings.

Where Keller’s historical explorations focus largely on gender in the conceptual structure of the biological sciences, Donna Haraway (2000; 1991; 1989) provocatively traces the study of gender into the material artifacts through which human societies embody their understandings of nature. In her widely admired history of primate displays in the American Museum of Natural History, Haraway argued that these representations encode deeply engrained cultural attitudes toward gender, its place in human nature, and its varied social manifestations, as for example in accepted understandings of the family. Haraway also led the way in arguing that the dominant paternalistic order of Western societies is engineered into the very design of technological systems. She, like Latour, is intensely aware of the hybrid constructions – *cyborgs*, in her language – that populate modern societies, but her aim in displaying the interconnectedness of things, norms and institutions has a more overtly political edge, inviting and celebrating female engagement through a wild inventiveness of language and association that makes traditional work in actor-network theory look almost businesslike by comparison.

Gender, though intensively studied, is not the only cultural category that can be absorbed into scientific practice, naturalized, and made invisible in everyday routines of research. Race, colonial relations and social class have all been

sustained by work in the human and life sciences, from anthropology to medicine and genetics (Reardon 2001; Stepan 1982). As yet, however, studies of science and technology have only begun to look for the often subtle incorporation of other cultural categories in the practice and content of scientific knowledge-making. That cultural features can enter into the life world of scientists is recognized in the work of anthropologists of science, such as Sharon Traweek's (1988) sensitive portrayal of high-energy physics communities in Japan and the United States and Rabinow's (1999) account of a dispute over genetic patrimony in France. More controversial, but of potentially greater interest to politics as well as science, are the efforts of some historians to show how culture may condition the processes of scientific inquiry, producing different styles of research on the "same" problems of knowledge (Harwood 1993).

Perhaps the most important question raised by interactional S&TS work on science and the state, as well as in feminist and cultural studies of science, concerns the direction of the influence of knowledge on power. Should power be seen as lodged in obdurate social structures which (as in work by Noble, Winner, and Haraway) constrain the production of potentially dissident knowledges; or is it fluid, immanent, and continually renegotiable, so that it can be captured or reformulated by inventive, upstart knowledge communities? Power, conceived in the former way, can be seen as continually reinscribing itself in the institutions, communities, practices, discourses, claims and products of science and technology, including not least our conceptions of human bodies and human nature. The problem of change, however, looms large if one adopts this stance too rigidly. If power is so entrenched and so hierarchical, replicates itself so freely, and reinscribes itself so effectively, then where does the impetus for change come from, and why are old orders sometimes suddenly overthrown?¹² On the other hand, refusing to acknowledge that some formations do retain power over long periods, and failing to ask how they achieve this stability, has embroiled S&TS scholars in charges of both moral relativism and prejudiced or uncritical subservience to paternalistic political orders. The co-production idiom, embracing as it does the constitutive as well as the interactional lines of thought, may offer at least a partial release from these dilemmas. It provides, following Latour and Foucault's later work, the possibility of seeing certain "hegemonic" forces not as given but as the (co-)products of contingent interactions and practices. These insights may, in turn, open up new opportunities for explanation, critique and social action.

Patterns of co-production

I have shown thus far that there is no dearth of work in science and technology studies from which to draw insights into the co-production of natural and social order. With greater and lesser self-consciousness, both the constitutive and the interactional traditions in the field have already made substantial inroads into social theory and political philosophy. The challenge is to piece together these theoretical contributions in a sufficiently programmatic form to open up a

distinctive research arena for normatively minded students of science and technology, as well as to engage in a more ambitious discourse on power and culture with the traditional social science disciplines. Put differently, our aim is to make the idiom of co-production more tractable so as to encourage conversation with other approaches to political and social inquiry.

Theoretical synthesis, to be sure, seems inconsistent with the temper of a field that has tended to reject totalizing stories – whether positive or negative – concerning science and technology. The emphasis on the contingent, the locally and temporally situated, the tacit and the ambivalent in accounts of discovery and innovation stands in opposition to univocal grand narratives. S&TS research has repudiated equally the triumphalist themes of progress and emancipation associated with Enlightenment views of science, and the pessimistic images of technology as disciplinarian, despot or iron cage, ruthlessly imposing its instrumental rationality on human behavior, that have informed decades of European philosophical and sociological thought (Habermas 1975; Ellul 1964). In their place, S&TS has sought to create a picture that remains profoundly humanistic, stressing the roots of science and technology in human agency and will, but denying any singular logic or design. Accordingly, S&TS has generated a wealth of detail about accommodations made by particular practitioners to specific, messy, local challenges in encounters that smack more of *bricolage* than of an idealized scientific method. Skeptical of claimed patterns and *post-hoc* generalizations, such work offers at first sight inhospitable material from which to weave more general doctrines connecting natural and social order. Nonetheless, as this volume shows, the attempt is distinctly worth making.

Co-production's theoretical ambitions

Biological analogies are risky tools for the social sciences, as we know from numerous dubious or discarded research programs that built on biological models; examples include research on natural law, eugenics, race, and social Darwinism. Nonetheless, the problem faced by the social sciences today is not unlike the dilemma that Richard Lewontin describes for the biological sciences following the genetic revolution. If we recognize, as he and others have done, that exclusively genetic explanations of biological phenomena are impossibly reductionist, and that causes almost always entail reciprocal interactions between genes, organisms and the environment (Lewontin calls this the "triple helix" in contrast to DNA's double helix), then how can we meaningfully accommodate this level of complexity into our accounts of the world? As Lewontin (2000: 109) observes,

It is easy to be a critic. All one needs to do is to think very hard about any complex aspect of the world and it quickly becomes apparent why this or that approach to its study is defective in some way. It is rather more difficult to suggest how we can, in practice, do better.

Can the co-productionist framework in science studies, like Lewontin's proposed program for evolutionary biology, avoid the trap of reductionism without falling into a mind-numbing holism?

We have already noted (see Chapter 1) that the idiom of co-production most readily aligns itself with the interpretive and post-structuralist turn in the social sciences (Jasanoff and Wynne 1998; Latour 1988b). Its aim is not to provide deterministic causal explanations of the ways in which science and technology influence society, or vice-versa; nor is it to provide a rigid methodological template for future S&TS research. Rather, it is to make available resources for thinking systematically about the processes of sense-making through which human beings come to grips with worlds in which science and technology have become permanent fixtures. Science and values, objectivity and subjectivity, and indeed intersubjectivity, can thereby be reintegrated into explanatory projects that conform more accurately to the lived experience of modern societies. The picture of human beings and their institutions as *knowing* agents fills some of the void left by statistically oriented social sciences that treat these entities as calculative actors choosing rationally – which all too often means ahistorically and aculturally – among taken-for-granted preferences. Far from denying the reality or the power of science, co-production goes some distance toward explaining why the products of science and technology acquire such deep holds on people's normative instincts as well as their cognitive faculties.

We observed as well in Chapter 1 that work in the co-productionist idiom has tended to cluster around four recurrent themes. These are the *emergence and stabilization* of new technoscientific objects and framings, the staple concern of constitutive co-production; and, on the interactional side, the resolution of scientific and technical *controversies*; the processes by which the products of technoscience are made *intelligible and portable* across boundaries; and the adjustment of science's *cultural practices* in response to the contexts in which science is done. In each of these areas, work in the co-productionist idiom stresses, as we have seen, the constant interplay of the cognitive, the material, the social and the normative. Co-production, moreover, occurs along certain well documented pathways. Four are particularly salient, as illustrated in the chapters that follow: making *identities*, making *institutions*, making *discourses* and making *representations*. It is useful to acknowledge and briefly describe these, because they help connect the science studies literature to work on similar topics in political and social theory.

Each of these instruments of co-production can serve varied functions in maintaining order. They can be *morally* or *metaphysically* sustaining, in that they divide the world of hybrids and cyborgs into less ambiguous categories that can easily be dealt with in law and custom. In spite of her ambivalent identity, for example, the cloned sheep Dolly remained for the duration of her short life firmly encamped in the company of domestic animals, as just another product of "ordinary" animal husbandry. Despite her unique ontology as a willed, exact genetic copy of another living creature, Dolly was not treated as something wild or unnatural that resists classification – as would, for now, a cloned Bill Gates or

Osama bin Laden. Scientific and technological products also do metaphysical work in preserving critical boundaries between self and other, structure and agency, state and citizen. The identities, institutions, languages and representations created by science and technology can be *politically* sustaining, by helping societies to accommodate new knowledges and technological capabilities without tearing apart (indeed, often by reaffirming) the legitimacy of existing social arrangements. Finally, they can be *symbolically* sustaining, providing surrogate markers for the continued validity of certain familiar dispensations when uncertainties threaten to overwhelm or disrupt them; examples include, in some liberal democracies, the presumed superiority of markets over state regulation, or the equally mythologized one-to-one correspondence between votes cast and voter intent (see Lynch 2001).

Ordering instruments

How, more specifically, does each of the four most common instruments of co-production operate at the nexus of natural and social order? How do they stabilize both what we know and how we know it?

Making identities

A staple category of post-structuralist social analysis, identity is particularly germane to co-productionist accounts because, whether human or non-human, individual or collective, it is one of the most potent resources with which people restore sense out of disorder. When the world one knows is in disarray, redefining identities is a way of putting things back into familiar places.¹³ It is no surprise, then, that co-productionist writing in science and technology studies, concerned as it so often is with emergent and controversial phenomena, has consistently been absorbed with questions of identity. The formation and maintenance of identities plays an important role in several of the contributions to this book. The identity of the expert, in particular, that quintessential bridging figure of modernity, makes a prominent appearance in several of the chapters (Rabeharisoa and Callon, Lynch, Carson, Dear, Dennis). But collective identities are also contested or under negotiation in the working out of scientific and technological orders. What does it mean to be "European" (Waterton and Wynne), "African" (Thompson), "intelligent" (Carson) or a member of a research community, learned profession or disease group? And what roles do knowledge and its production play in shaping and sustaining these social roles or in giving them power and meaning?

Making institutions

Institutions play a crucially important role in co-productionist accounts of world-making, as they do in social analysis writ large. As stable repositories of knowledge and power, institutions offer ready-made instruments for putting

things in their places at times of uncertainty and disorder. They may be regarded in this sense as society's *inscription devices* (see Latour 1987; Latour and Woolgar 1979) – vehicles through which the validity of new knowledge can be accredited, the safety of new technological systems acknowledged, and accepted rules of behavior written into the as-yet-unordered domains that have become accessible through knowledge-making. As Mary Douglas (1986) wrote in *How Institutions Think*, successful institutions classify, confer identity, act as repositories of memory and forgetting, and make life-and-death decisions for society.

Institutionalized ways of knowing things are continually reproduced in new contexts (Jasanoff 2001), either because they are socialized into actors and therefore unquestioningly reenacted, or because it would be too disruptive to reexamine them openly. For example, in market capitalism, the human subject is imagined as being able to form autonomous preferences, process information, make rational choices, and act freely upon the choices so made; the human subject's failure to behave as predicted is usually attributed to the market's failings (for example, barriers to information) and not to deficiencies in the underlying model of individual agency. As we have seen, such tacit models of human agency, and consequently of human nature, frequently underpin the technical discourses through which public institutions carry out their regulatory activities (Scott 1998; Irwin and Wynne 1994).

Institutions also serve as sites for the testing and reaffirmation of political culture. Through institutions such as legal systems and research laboratories, societies have access to tried-and-true repertoires of problem-solving, including preferred forms of expertise, processes of inquiry, methods of securing credibility, and mechanisms for airing and managing dissent. Solidified in the form of administrative routines, these repertoires offer constant fall-back positions from which responses to novel problems can be constructed. As all the chapters in this volume demonstrate to one or another degree, co-production could hardly be conceived in the absence of institutions, partaking of their resilience as well as their plasticity. When environmental knowledge changes, for example, new institutions emerge to provide the web of social and normative understandings within which new characterizations of nature – whether climate change, endangered elephants or agricultural science (Miller, Thompson, Storey) – can be recognized and given political effect. In other policy settings, institutions are required to interpret evidence, make law, standardize methods, disseminate knowledge or ratify new identities. Treating these functions as integral to the work of institutions offers an obvious point of contact between co-productionist work in science and technology studies and new institutionalist approaches in sociology and political theory.

Making discourses

Solving problems of order frequently takes the form of producing new languages or modifying old ones so as to find words for novel phenomena, give accounts of experiments, persuade skeptical audiences, link knowledges to practice or action,

provide reassurances to various publics, and so forth. As many of the following essays illustrate, such strategies often involve the appropriation of existing discourses (legal, medical and ethical languages, for example) and their selective retailoring to suit new needs. In the process, scientific language often takes on board the tacit models of nature, society, culture or humanity that are current at any time within a given social order. As Rabearisoa and Callon and Lynch most explicitly illustrate, but as is also suggested in several other chapters, social discourses such as law or the speech of patients may similarly incorporate and reinforce tacit understandings of science.

Discursive choices also form an important element in most institutional efforts to shore up new structures of scientific authority. Thus international environmental organizations, such as the European Environment Agency (Waterton and Wynne) or the Intergovernmental Panel on Climate Change (Miller), had to develop persuasive ways of speaking about the problems over which they exercised jurisdiction. Such efforts inevitably entail standardization, which may bring its own dilemmas of oversimplification and vulnerability to deconstruction in encounters between experts and skeptics (Carson, this volume; Jasanoff and Wynne 1998; Jasanoff 1992; 1986). While institutional discourses often tacitly merge normative and technical repertoires, as in many economic models, they may also enable reasoned action by defining the boundary between the promising (“natural” or “safe”) and the fearsome (“unnatural” or “unsafe”) aspects of nature and technology. Thompson's chapter on the substitution of a loosely managed, variably threatened African elephant for a globally threatened “endangered species” illustrates such a productive questioning and redefinition of boundaries.

Making representations

The nature of representation has been a core concern of S&TS since the earliest attempts to understand scientific knowledge in social terms. Much sensitive work has been done on the means, both human and material, by which scientific representations are produced and made intelligible in diverse communities of practice, but the connections between this work and that of political and social representation has not always been apparent. The contrast drawn earlier between Latour's analyses of representation and those of Anderson and Scott alerts us to the desirability of enlarging on the theme of representation in science studies, making its political implications more explicit. We may note in this context three aspects of representation that have begun to receive attention from scholars working in the co-productionist idiom, including those in this volume: historical, political and cultural influences on representational practices in science; models of human agency and behavior that inform representation, especially in the human and biological sciences; and the uptake of scientific representations by other social actors. The results of this broader engagement with the politics of representation are apparent throughout this volume, most particularly in Ezrahi's concluding chapter.

We are at last in a position to return to the questions posed early in this chapter as large challenges for the framework of co-production. Can this approach describe, explain, critique, and perhaps even predict phenomena in ways that make it a useful added resource in the project of social analysis? What, in sum, can co-productionist accounts add to our understanding of knowledge societies or of knowledge in society? Does co-production usefully integrate the insights of work in science and technology studies to provide something approaching a coherent research program, though one that can be pursued with a generous plurality of methods and objectives?

Most immediately apparent is the idiom's descriptive richness. It sweeps back into the analyst's field of vision connections between natural and social orders that disciplinary conventions often seek to obliterate, thereby doing injustice to the complexity as well as the strangeness of human experience. This ability to reframe the phenomena of the world in novel ways is what also gives co-productionist stories their explanatory power. Without being reductionist or monocausal, these accounts nevertheless attempt to answer certain kinds of questions that might otherwise remain baffling or, worse, not even acknowledged as important. How do new sociotechnical objects – such as climate change or endangered species, or for that matter Europe, Africa or democracy – swim into our ken, achieving cognitive as well as moral and political standing? How is knowledge taken up in societies, and how does it affect people's collective and individual identities, permitting some to be experts, others to be research subjects, and still others to be resisters or revolutionaries? By making visible such questions, and proposing answers that were not previously on the table, co-productionist analysis performs a neglected critical function. More conventionally, though no less importantly, it enables normative analysis by following power into places where current social theory seldom thinks to look for it: for example, in genes, climate models, research methods, cross-examinations, accounting systems or the composition and practices of expert bodies. Prediction is the hardest case, and one may well wonder why in our surprise-prone societies any social science ever purports to tell the future. But to the extent that co-production makes apparent deep cultural regularities, to the extent that it explains the contingency or durability of particular socio-technical formations, it also allows us to imagine the pathways by which change could conceivably occur. It illuminates, in this way, new possibilities for human development.

The essays in this collection should certainly lay to rest the charge that the field of science and technology studies is insufficiently normative and has little to contribute to macro-social analyses of culture and power. On the contrary, they demonstrate that some of the most enduring topics in politics and government lend themselves well to elucidation in a co-productionist mode. Among these are the emergence of new authority structures and forms of governance, the (selective) durability and self-replication of cultures, and the bases of expert conflict over knowledge in rational, democratic societies. The essays also establish a point that has become increasingly clear across the spectrum of S&TS research: that historical and contemporary voices in the field have a lot more in common than

has been permitted to surface across institutionalized disciplinary boundaries. Regardless of the observer's standpoint in time, there is in these pieces a shared outlook on the nature of knowledge and its embeddedness in material and social forms. Perhaps as important, in one after another of these chapters, the distinction between “micro” and “macro” that has played so foundational a role in traditional social theory is shown to be, in significant part, an artifice of our own thought processes. In practical experience, the scales of analysis and action are frequently scrambled together. The national or global constitutional orders we recognize and live by are constantly remade in innumerable, localized engagements; without this perpetual reperformance they might as well cease to exist. Co-production, then, allows the bringing together of insights from anthropology and history, law and politics, cultural studies and social theory. It is an *integrative* as well as an interdisciplinary framework.

S&TS as a field has been criticized, finally, for making science too “social” – to the point, some say, of representing science as no different from any other exercise in the accumulation of authority. I have indicated already that this thin reading misrepresents the breadth and sophistication of the field's engagement with the social worlds in which science and technology function today as indispensable players. This book, at any rate, freely acknowledges the cultural uniqueness of science and technology, insisting only that their specialness arises from repeated, situated encounters between scientific, technical and other forms of life. More particularly, the volume invites readers to reflect on the plastic and infinitely varied adjustments through which science and technology infuse, and are infused by, other ways of knowing, perceiving, and making accommodations with the world. Unlike “laws of nature”, the idiom of co-production does not seek to foreclose competing explanations by laying claim to one dominant and all-powerful truth. It offers instead a new way of exploring the waters of human history, where politics, knowledge and invention are continually in flux. On that voyage, we hope, this volume will serve as an informative companion.

Notes

- 1 Dolly, for instance, was incorporated for a time into the sequence of images that introduces CNN's news programs. These pictures are not only seen around the world wherever CNN has an audience, but constitute in the process a visual lexicon of instant recognizability whose elements require neither comment nor translation. They operate, in Ezrahi's terms as “outformations” (see his essay, this volume). They are part of the mass media's repertoire of reality that sometimes contravenes but sometimes also reinforces the realities produced by science.
- 2 To avoid any such implication, Bruno Latour and Steve Woolgar changed the subtitle of their seminal study of laboratory science from “The social construction of scientific facts” in the original 1979 edition to “The construction of scientific facts” in the 1986 edition (Latour and Woolgar 1979; see also 1986 edition).
- 3 An example of such black-boxing that has been widely discussed in the S&TS literature appeared in an article calling for science studies researchers explicitly to take sides with the “underdogs” in political controversies, since they could not possibly remain “neutral”. See Scott *et al.* (1990). For a series of rejoinders taking apart the social black-boxes invoked by these authors, see Malcolm Ashmore and Evelleen

Richards (eds) (1996) "The Politics of SSK: Neutrality, Commitment and Beyond", *Social Studies of Science* 26(2): 219–468.

- 4 A parallel may be drawn here with Richard Lewontin's criticism of holistic theories in biology. Lewontin (2000: 110) observes,

Everything is not effectively connected to everything. While gravitational perturbations do indeed spread out into the indefinite distance, one can stir a flower without troubling a star, because gravitation is a weak force that decreases as the square of the distance between objects.

Science studies has rightly questioned a realist view of the world that ascribes to science, writ large, something like Lewontin's gravitational force, with power to spread out into indefinite space. At the same time, the answer is not to substitute for the once unanalyzable category called "science" a term like "network", whose internal structure and function also resist sociological or normative analysis.

- 5 Scott evidently assumes that the children were in this manner expressing their resistance to their highly anonymous living circumstances. Having drawn precisely such pictures as a child in Calcutta, where houses with pitched roofs are virtually unknown, I wonder whether the experiment does not sooner illustrate a different and perhaps more insidious standardization of images of the "home" through children's books, films and other cultural materials produced in the West. Still, the basic point remains that none of the children "saw" the apartment blocks they lived in with sufficient clarity or sense of ownership to render them in their drawings.
- 6 Speaking of the lowest caste of outcasts during the Tokugawa period, Ruth Benedict says in her famous anthropological study, "They were Japan's untouchables, or, more exactly, their uncountables, for even the mileage of roads through their villages went uncounted as if the land and the inhabitants of the area did not exist at all" (Benedict 1989: 61). In Scott's terms, the outcasts were wholly illegible, and they remained so until the Meiji restoration of the nineteenth century. Their position contrasts strikingly with those of the other four castes – warriors, farmers, artisans and merchants – whose legibility the Shoguns ensured through a host of restrictions, from sumptuary laws to controls on vocation and movement.
- 7 I am indebted to Stefan Sperling for drawing my attention to this point. In the present period, a company like Amazon sorts and characterizes its readers no less effectively than hospitals do their patients; readers are thereby rendered legible. Moreover, such powerful marketing technologies, with their resulting consumer debts, may do as much to capture people and keep them in their place as official correctional institutions once used to do.
- 8 The point to stress here is that science was, for both Polanyi and Merton, *the* model polity. Both men were concerned to identify science with the liberal values that had been cruelly jettisoned by the mid-century's totalitarian regimes. Their views can be contrasted with Richard Rorty's statement that "the only sense in which science is exemplary is that it is a model of human solidarity" (Rorty 1989: 14–15).
- 9 Winner borrowed this example, which has become something of a byword in science and technology studies, from Robert Caro's (1974) biography of New York City's great and controversial planner Robert Moses. For an account that disputes Winner's reading of the example, see the article by Bernward Joerges (1999).
- 10 In his full account, Storey makes clear that the colonial regime did not wholly relinquish its scientific advantage by giving the hybrid varieties to the small planters. To stabilize sugar production further, the government created a new "Central Board" to arbitrate disputes between factories and planters. The Central Board kept the millers from making unlawful deductions against the small planters' canes, but it also used chemical analysis to demonstrate the canes' inferior sucrose content, thus strengthening the case for lower payments.

- 11 Ezrahi assumes the possibility of unmediated vision that allows citizens to see and judge for themselves the work of the state, as in America's space program of the 1960s. Recent "virtual wars" in places like Kuwait, Kosovo and Afghanistan have demonstrated the amount of work the state needs to do in order to make its displays conspicuous to citizens, from controlling its press releases to monitoring the media to selecting the pictures that will be available for distribution. At the same time, these globally televised wars underscore the validity of Ezrahi's basic point that technology has become an indispensable instrument for creating public displays of the state's legitimacy. In his essay in this volume, Ezrahi provocatively explores the contradictions between scientific and media representations of reality.
- 12 This problem is analogous to the issues that anthropologists have confronted in speaking about culture. If culture is taken as (relatively) unchanging, then how can one avoid falling into the trap of thinking that it is "stereotypically" reproduced? For an illuminating discussion, see Sahlins (1995).
- 13 For example, *in vitro* fertilization, combined with the possibility of using a surrogate mother for gestation, opens up the need to redefine the meaning of so basic a social identity as "mother". The discovery that the human genome is virtually identical in all human beings reopens the perennial controversy about the meaning of race. The recognition that the earth is an enclosed space with finite resources, a biosphere, calls for imagining the human subject as a global citizen.