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My gratitude to the colleagues who contributed to the volume is almost beyond words, but it is important to note that their efforts are only partly reflected in the chapters they have written. Invisible but all-important intellectual work was done over many years while we collectively deliberated how to tackle the problem of science and social order in ways that would bring science and technology studies into productive dialogue with more traditional analyses of power and culture. Through corridor conversations and informal email exchanges, workshop meetings and, eventually, formal papers, we managed to overcome our disciplinary divisions and to create a discourse that was rigorous enough to give us shared analytic ground rules, yet flexible enough to accommodate highly varied, personal choices of topic, period, style and method.

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1 The idiom of co-production

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Science and technology permeate the culture and politics of modernity. On any day, the headline news provides crude but telling indicators of their influence. A Martian ethnographer visiting planet Earth in the first few years of the third millennium would have encountered a bewildering array of stories whose only discernible connection would have been the pervasive – though perversely inconsistent – role of science and technology in human affairs. The millennium opened with false fears of the so-called Y2K bug that might have made computer systems throughout the world crash at midnight, when 1999 rotated into 2000. In 2001, the seemingly well regulated technological system of American civil aviation was ferociously turned upon itself by young Islamic militants, who not only destroyed New York's tallest buildings, the twin towers of the World Trade Center, but used planes to expose unsuspected vulnerabilities at the heart of US domestic security. In retaliation, the United States launched two militarily successful wars in Afghanistan and Iraq, demonstrating that the advent of “smart weapons” had radically altered the dynamics of battle since the Vietnam era; by the official end of the Iraq invasion, some US observers even wondered (in a luxury permitted only to winners) whether modern warfare any longer needed human bodies on the front lines. Early 2003 also saw the loss of the US space shuttle Columbia with seven crew members, underlining again the fragility of manned space exploration. Behind the dramatic disasters and the violence of terrorism and war, ordinary human attempts to master nature proceeded at slower rhythms, as societies debated how to manage global climate change, AIDS, and other epidemic diseases; how to solve problems of clean water and renewable energy; how to improve crop yields without endangering farmers' livelihoods; how to treat the ancient infirmities of aging, infertility, mental illness, and disease; and how to stave off death itself.

Yet, in analyzing many of the defining phenomena of human history – those arising at the nexus of science, technology, culture and power – large segments of the social sciences seem almost to retreat into a conspiracy of silence. In a world increasingly driven by the market's logic, and by the discovery of knowledge as a resource, neoclassical economics and rational choice models have sought to explain why firms innovate and how governments can steer research and development for higher productivity (Branscomb and Keller 1998; also see Rosenberg

1994; Mowery and Rosenberg 1989). But these approaches provide at best schematic accounts of the varied human responses to climate change, biological weapons, mammalian cloning, genetically modified foods, new reproductive technologies, emerging diseases, loss of biodiversity, techniques of miniaturization, and the growth of the internet. Entailing prolonged, contested interactions among people, ideas, institutions and material objects, the recognition and uptake of these phenomena challenge many of the most basic categories of social thought – such as structure and agency, nature and culture, science and politics, state and society. The dominant discourses of economics, sociology and political science lack vocabularies to make sense of the untidy, uneven processes through which the production of science and technology becomes entangled with social norms and hierarchies. Still less do these conceptual frameworks allow us to evaluate how sociotechnical formations loop back to change the very terms in which we human beings think about ourselves and our positions in the world (Hacking 1999; 1992; Foucault 1972). Anthropology, with its focus on thick description (Geertz 1973) and its growing attentiveness to modern, non-exotic cultures, does better at the project of sense-making, but at the risk of losing historicity, overemphasizing locality, and sacrificing some of the abstracting and generalizing capacities of the other social sciences (but see, for example, Gingrich and Fox 2002).

By contrast, the emerging field of science and technology studies (S&TS) has adopted as its foundational concern the investigation of knowledge societies in all their complexity: their structures and practices, their ideas and material products, and their trajectories of change. Growing from many disciplinary roots – including history, philosophy, sociology, politics, law, economics and anthropology – S&TS today encompasses a rich tapestry of theoretical and methodological perspectives, all specifically directed toward investigating the place of science and technology in society (Jasanoff *et al.* 1995). Conversations between S&TS and neighboring fields about the links between knowledge, culture and power are therefore urgently needed and could be enormously fruitful. To further these discussions, however, disciplinary divisions within S&TS must be bridged, and more explicit efforts made to link the field's predominant concerns with those of the traditional social sciences. This book takes on both tasks by elaborating the concept of *co-production*, which has recently gained ground in diverse domains of S&TS research.

The book's main argument is that, in broad areas of both present and past human activity, we gain explanatory power by thinking of natural and social orders as being produced together. The texture of any historical period, and perhaps modernity most of all, as well as of particular cultural and political formations, can be properly appreciated only if we take this co-production into account. Briefly stated, co-production is shorthand for the proposition that the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it. Knowledge and its material embodiments are at once products of social work and constitutive of forms of social life; society cannot function without knowledge any more than

knowledge can exist without appropriate social supports. Scientific knowledge, in particular, is not a transcendent mirror of reality. It both embeds and is embedded in social practices, identities, norms, conventions, discourses, instruments and institutions – in short, in all the building blocks of what we term the *social*. The same can be said even more forcefully of technology.

Co-productionist accounts, conceived in this way, avoid the charges of both natural and social determinism that have featured in recent academic debates around the field of science and technology studies, including the infamous “science wars” of the 1990s (Sokal and Bricmont 1998; Koertge 1998; Gross and Levitt 1994). Science, in the co-productionist framework, is understood as neither a simple reflection of the truth about nature nor an epiphenomenon of social and political interests. Rather, co-production is symmetrical in that it calls attention to the social dimensions of cognitive commitments and understandings, while at the same time underscoring the epistemic and material correlates of social formations. Co-production can therefore be seen as a critique of the realist ideology that persistently separates the domains of nature, facts, objectivity, reason and policy from those of culture, values, subjectivity, emotion and politics. However, co-production, in the view of contributors to this volume, should not be advanced as a fully fledged theory, claiming lawlike consistency and predictive power. It is far more an idiom – a way of interpreting and accounting for complex phenomena so as to avoid the strategic deletions and omissions of most other approaches in the social sciences.

The essays in this collection, then, endeavor to address audiences within S&TS and in neighboring social sciences, as well as interested readers in the humanities, sciences and policy institutions. As is implied by the book's title, *States of Knowledge*, a significant aim of several of the contributors is to explore how knowledge-making is incorporated into practices of state-making, or of governance more broadly, and, in reverse, how practices of governance influence the making and use of knowledge. States, we may say, are made of knowledge, just as knowledge is constituted by states. But the title also plays on the theme of co-production at additional levels. Knowledge, in particular, is seen as crystallizing in certain ontological states – organizational, material, embodied – that become objects of study in their own right.¹

The authors seek to illuminate some shared concerns as well as some possible tensions between S&TS and more established fields. In pursuing these objectives, the book attempts to synthesize findings from the various subfields of science and technology studies (e.g. history of science, technology studies, sociology of scientific knowledge, feminist and cultural studies of science and technology, science and law, and science policy studies). Not all of the synthesis, however, is internalist, working exclusively within the core of S&TS. Once we approach the interconnectivity of nature and society with a co-productionist vision, we find echoes of and parallels to the concerns of science studies in other interpretive social sciences, from anthropology to political theory. Exploring some of these convergences is as much a project of this book as theorizing across S&TS. Indeed, the book makes explicit efforts to link literatures that have not previously

been in conversation, revealing connections that should not only interest S&TS researchers but reverberate throughout the social sciences.

That said, a major purpose of the synthesis offered here is to highlight some cross-cutting theoretical assumptions in S&TS scholarship, as well as their normative implications, showing why S&TS methods and findings are indispensable for the analysis of power, culture and social change. Coming from disciplinary backgrounds in history, politics, sociology, law, anthropology, physics and science studies, the contributing authors vary in their research focus and methodological preferences; yet they epitomize the common orientations of many S&TS scholars toward the relationship between knowledge and social order. In jointly presenting their views on co-production, the authors emphasize the analytic achievements of S&TS as a whole in relation to other areas of current humanistic and social thought. They also help contradict certain frequent but unfounded criticisms of S&TS scholarship: that it is too micro-focused to speak convincingly to social theory; too internalist in its focus on science and technology to hold interest for students of other social phenomena; and too lacking in normative bite to be sufficiently critical (Woodhouse *et al.* 2002; Scott *et al.* 1990).

The idiom of co-production speaks to the agendas of the traditional social sciences (and to some extent the humanities) in a number of ways. It fits most comfortably with the interpretive turn in the social sciences, emphasizing dimensions of meaning, discourse and textuality. This approach addresses and complements a number of specific disciplinary lines of thought. To political scientists, particularly those working in post-structuralist frameworks, co-production offers new ways of thinking about power, highlighting the often invisible role of knowledges, expertise, technical practices and material objects in shaping, sustaining, subverting or transforming relations of authority. To sociologists and social theorists, the co-production framework presents more varied and dynamic ways of conceptualizing social structures and categories, stressing the interconnections between the macro and the micro, between emergence and stabilization, and between knowledge and practice. To anthropologists, it offers further tools for analyzing problems of essentialism and stereotypic reproduction, showing how the cultural capacity to produce and validate knowledges and artifacts can account for long-term stability, as well as creativity and change. Finally, co-productionist accounts take on the normative concerns of political theory and moral philosophy by revealing unsuspected dimensions of ethics, values, lawfulness and power within the epistemic, material and social formations that constitute science and technology.

In all these respects, the co-productionist approach in S&TS is entirely compatible with projects in the history of science and technology. It is hardly surprising, then, that several contributors to this volume are historians by training (Carson, Dear, Dennis, Storey). An important value of the co-production idiom is that it may encourage more fruitful dialogue between historical and contemporary studies of science and technology, denying temporality the right to operate as a preordained conceptual and methodological barrier within S&TS. As co-

productionist studies make clear, investigations of current science and technology stand to benefit immeasurably from greater historical depth, just as historical work may gain profoundly and relevance through more explicit attention to questions of power, culture and normativity.

Research elaborating on the idea of co-production has condensed around a number of shared theoretical questions and their methodological consequences. At what levels of social aggregation (laboratories, communities, cultures, the nation, the state, all of humanity), and in what kinds of institutional spaces or structures does it make sense to look for co-production? Put differently, what is it that gets co-produced in nature and society? Are the most useful insights about co-production to be discovered at the level of science, power and culture writ large? Or is it more illuminating to trace in fine-grained detail how particular concepts for classifying or ordering social worlds – for example, selfhood, national identity, illness or wellness, professional standing, expertise, citizenship – gain, or have gained, stability and coherence, along with equally particular expressions of knowledge – for example, genetic markers, measures of human intelligence, climate change, agricultural science, or the scarcity of elephants? The essays in this volume demonstrate that there is no necessary unanimity about these matters in current research in the co-productionist framework; rather, the very open-endedness of the authors' methodological choices, along with the diversity of their substantive topics, gives this turn in S&TS scholarship some of its undeniable exuberance. At whichever scale individual studies are framed, though, the findings help to clarify how power originates, where it gets lodged, who wields it, by what means, and with what effect within the complex networks of contemporary societies.

Several recurrent and partially overlapping preoccupations in S&TS scholarship offer a means of organizing (and, in the future, fostering) work in the co-productionist idiom. The first has to do with the *emergence and stabilization* of new objects or phenomena: how people recognize them, name them, investigate them, and assign meaning to them; and how they mark them off from other existing entities, creating new languages in which to speak of them and new ways of visually representing them (Daston 2000; Dear 1995; Pickering 1995; Latour 1993; 1988a). The second concerns the framing and resolution of *controversy*. Under this heading, a large body of S&TS research has looked at the practices and processes by which one set of ideas gains supremacy over competing, possibly better established ones, or fails to do so (Richards and Martin 1995; Shapin and Schaffer 1985; Collins 1985). The third important line of research centers on the *intelligibility and portability* of the products of science and technology across time, place and institutional contexts. Topics under this heading range from the standardization of measures and analytic tools to the formation of new communities of practice, such as expert witnesses, who are capable of endorsing claims with credibility as they are transported across different cultures of production and interpretation (Bowker and Star 1999; Jasanoff 1995; Shapin 1994; Porter 1992; Latour 1987; Kuhn 1962). The fourth significant tradition examines the *cultural practices* of science and technology in contexts that endow

them with legitimacy and meaning. Work in this vein has asked how the supposed universality of facts and artifacts fares in disparate political and cultural settings, as well as how different domains of research and development acquire and retain particular cultural characteristics (Knorr-Cetina 1999; Rabinow 1996; Traweck 1988).

In each of these four focal areas – the emergence of new phenomena, the resolution of conflicts, the standardization of knowledge or technology, and the enculturation of scientific practices – work in the co-productionist idiom stresses the constant intertwining of the cognitive, the material, the social and the normative. Co-production is not about ideas alone; it is equally about concrete, physical things. It is not only about how people organize or express themselves, but also about what they value and how they assume responsibility for their inventions. Equally to the point, co-production occurs neither at random nor contingently, but along certain well documented pathways. Four sites of co-production are repeatedly investigated by the contributors to this volume: making *identities*, making *institutions*, making *discourses* and making *representations*. These provide an important bridge between the S&TS literature and many of the core productions of traditional political and social analysis, which also revolve around these basic analytic categories.

Essays in co-production

As an interpretive framework, co-production begs for illustration rather than proof. The chapters that follow display the idiom's breadth and plasticity, but in working out co-productionist ideas through detailed empirical studies, they also demonstrate the framework's practical uses and limits. In the next chapter, I make the theoretical case for co-production as an analytically useful concept by delineating the spaces it seeks to fill between dominant frames of analysis espoused by the social sciences. The chapter provides a detailed review of the S&TS literature that underwrites work in the co-productionist idiom. Here, we encounter two streams of thought: one focused broadly on the constitution of new technoscientific cultures, often around emergent ideas and objects; the other on solving problems of disorder within established cultures. I refer to these as the constitutive and interactional strands, respectively; they correspond broadly to well documented S&TS engagements with metaphysics and epistemology – or, as Hacking phrases it, "what there is and how we find out about it" (1999: 169). The chapter next outlines the programmatic aims of research on the theme of co-production and elaborates on the pathways by which co-production most often occurs. I conclude with reflections on how co-productionist ideas may help connect S&TS work to ongoing intellectual projects in other fields of social analysis.

The remaining chapters are grouped under three sets of thematic as well as topical headings. The first group – by Miller, Thompson, Waterton and Wynne, and Storey – looks at evolving perceptions of the environment and nature as sites of co-production; all these authors centrally engage with the simultaneous emergence of new knowledges, institutions and identities related to environmental

change. The second group, consisting of chapters by Hilgartner, Rabeharisoa and Callon, Lynch, and in part Carson, investigates co-production as related to developments in the human and life sciences, especially the practices of research communities in genetics, clinical medicine and forensic science. These chapters bring to the fore issues of intelligibility and portability of knowledge, linked to the formation of new social identities and expert discourses. The third group, by Carson, Dear, Dennis, and Ezrahi, addresses a complex of issues centering on the macro-politics of knowledge; they focus on institutional conflicts among cognitive, moral and political authority, the mediating presence of experts, and the role of science and technology at times of significant political change. The connections between scientific knowledge-making and other authoritative cultural practices (religion, military, media) figure importantly in these chapters, which also deal with conflicts between alternative institutionalized knowledge-power formations. In short, these chapters play upon the book's title – states of knowledge – in its most open and obvious meaning.

With these groupings in mind, let us turn to a more detailed review of the individual contributions. The theme of institutional and epistemic emergence, as already mentioned, is especially prominent in the chapters dealing with the construction and deployment of environmental knowledge and the building of transnational political orders. Clark Miller addresses these issues on a planetary, or global, scale. Creating environmental knowledge about the biosphere involves, he suggests, not only new sciences and technologies, such as satellite data, general circulation models and integrated assessments, but also the fabrication of new institutions whose authority can credibly span the globe. Globalization, on Miller's account, is not simply the result of pre-stabilized knowledges, beliefs, products and social identities traveling around the world. Rather, it requires the manufacture of a newly imagined global political order that both links and transcends earlier nation-based centers of knowledge and power. Miller shows how the framing of climate change as a global issue, replacing the earlier view of climate as an aggregation of local weather problems, supplied a rationale for creating global institutions with claims to both scientific and political legitimacy. Previewing several succeeding chapters, Miller also shows that the attempt to supersede existing political orders produces its own tensions, exposing disagreements about the nature of "good science" as well as "good politics" on a supranational scale.

In her account of elephant protection in Africa, Charis Thompson examines co-production from the standpoint of international environmental regimes. She questions the presumption that knowledge must be consolidated in particular places before it can travel freely to other locations. Thompson argues that the shift in the elephant's status from "endangered" to "manageable" was not due to a context-specific, scientific determination of elephant biology, but went hand-in-hand with the emergence of a pan-African identity that could support multi-sited management practices. Originally forced to accept an absolutist scientific discourse of endangerment, African nations were enabled, through successive rounds of international negotiation, to put forward their view that

elephants could be both hunted and protected in a regime of sustainable development. This "African" position, which merged ethics with science and made space for regional variation, successfully countered the monolithic bureaucratic rationality of some Western environmentalists. It produced, in effect, an authentically "African" elephant, unshackled by global discourse. A North-South dialogue that reopened divisions between lay and expert, and science and politics, led to the creation of a new moral economy around the elephant – thus making it possible to defend a new ontology for this most charismatic of all large animal species.

Claire Waterton and Brian Wynne also situate their study in the international arena as they examine how institutions and identities are bound up in processes of new knowledge formation. Their focus is on the European Environment Agency (EEA), a body that has been called upon to imagine and project a vision of Europe while at the same time shaping its own identity as a provider of objective, useful environmental knowledge to European policymakers. The agency sits at what one of its own analysts eloquently describes as "the eye of the hurricane" of European integration. The dilemma that Waterton and Wynne explore is that the EEA in a sense presupposes a full-blown European identity in order to legitimate its knowledge-producing activities; yet, in the very act of knowledge-making, the EEA participates in enacting Europe's nascent political order, choosing between models not yet set in stone. The evaluation of genetically modified (GM) crops and environmental chemicals illustrates the practical working out of this tension. The EEA, as Waterton and Wynne argue, recognizes that environmental uncertainty and risk demand new forms of deliberation and a critical approach to the existing centralized and officially sanctioned policy processes. At the same time, for its own legitimacy, as well as for the sake of the imagined, Platonic Europe that is aborning, the EEA cannot wholly let go of older assumptions of universal science and expert rationality. The EEA's experience in this respect is all about the messy and contested emergence of alternatives to the rationalizing, high-modernist state.

William Storey provides a historical counterpoint to the contemporary cases in his account of the foundation of the Imperial Department of Agriculture for the West Indies in 1898. The Department represented an institutional solution to a complex and overlapping set of problems: ecological and economic crisis in Britain's sugar-producing colonies; the unreliability of colonial science; Britain's changing imperial objectives and policies; and the urge to remedy, with the aid of science, perceived social problems that were deemed to be natural. As Storey observes, this was no simple case of science influencing politics or politics influencing science; rather, each set of practices – scientific and political – provided a rationale for the other. This interplay produced a powerful institutional form that was copied in agriculture departments throughout the world and provided a template for an emerging imperial politics.

The human and life sciences are particularly rewarding sites for co-productionist accounts because they are so often implicated in all of the important manifestations of this process discussed above: emergence, contestation, standardization and encl-

nuration. The second group of chapters engages with these dynamics, and the associated roles of several non-state actors, such as scientists, patient groups and litigating parties. Stephen Hilgartner usefully reminds us that the institutions involved in co-production need not be those of the state. Practices for creating and contesting ownership, Hilgartner demonstrates, are deeply embedded in laboratories, where they shape both the internal workings of science and science's relations with the outside world. In his study, the laboratory becomes a site in which the institutions of property and ownership are redefined. Appropriation practices in genome laboratories thus constitute an inseparable part of their technological structure, moral order and everyday operation. Hilgartner's genome scientists challenge essentialist understandings of some basic social science categories. Their discourse blurs the contrast between micro and macro, and they remake the notions of "public" and "private" science through situated debates about who owns what in the laboratory.

Rabeharisoa and Callon also discuss a new kind of non-state institution, the "reflexive organization", which cuts across accepted divisions between lay and expert actors, and facilitates inquiry in a domain that increasingly demands the participation of the patient as an active research collaborator as well as a traditional research subject. Their investigation of the Association of French Muscular Dystrophy Patients shows lay individuals negotiating details of research and practice that are ordinarily thought to be the monopoly of specialist clinicians and scientists. The incorporation of a genetic disease as an element of their identity empowers muscular dystrophy patients and their families to participate in both knowledge-making and political action. Appearing, as it were, on both sides of scientific practice – as researchers and researched – the patients negate the conventional distinction between subject and object that has animated the work of science; only by acting as subjects can patients provide their partners, the orthodox scientific investigators, with a viable object of study. Further, by shaping novel discursive and organizational practices, they reorder many widely held assumptions about how biomedical science should be done in the contemporary world.

Michael Lynch directs his analysis toward the co-production of expert and non-expert knowledges in the context of US common law trials in the late twentieth century. This process, Lynch argues, does not consist simply of drawing a boundary between the two domains. Rather, it requires definition of the very category of expert and the assignment of particular individuals to that category. His analysis of cross-examination shows that the expert's identity is founded not on an individual's control of recognized knowledge and skills, but through mundane conversations and humdrum instruments, such as courtroom presentation of the professional résumé. Like Hilgartner, Lynch problematizes the easy distinction between micro- and macro-analytic categories. Courts engaging with forensic scientific evidence, he argues, are oblivious to such theoretical distinctions. In examining the credentials of a forensic DNA expert, for example, the court problematizes the "macro" categories of "science" and "expert" by enabling micro-, context-specific, adversarial dialogues to occur between

witnesses and cross-examining attorneys. Lynch's "grammatical perspective" shows how the use of ordinary words allows courts to shift between two registers: on the one hand, paying homage to science's transcendence by seeming to honor the categories that set science apart; on the other hand, remaking the distinctions between science and common sense through case-centered decisionmaking. Courts in this way perform some of the essential political work of liberal democracies, by invoking and continually reproducing through their own practices the boundary between science and non-science.

John Carson turns his eye on a core problem of contemporary democracy, the fair distribution of scarce resources such as access to educational opportunities. Comparing the genesis of intelligence testing in early-twentieth-century France and the United States, he displays how one of the most taken-for-granted aspects of human identity — *intelligence* — has been configured in different ways in two different democratic cultures. Both intelligence and tests of it are emergent scientific objects, constituted through evolving expert discourses; but, going beyond normal accounts of science in the making, Carson's chapter compellingly delineates the *political* work done by these characterizations of human competence. Variations in the definition and measurement of intelligence between France and the United States can be attributed, he argues, to divergent understandings of equality in the two countries. In France, the democratic challenge is to represent existing social hierarchies as potentially open to all citizens. This has correlated with the assessment of merit through a standardized, state-administered educational system, in which performance according to collectively defined standards — not birth nor heredity — is the putative guarantor of success. In the United States, by contrast, hierarchies of merit are publicly disavowed, education is highly decentralized, and the federal role in rearing educated citizens is both constitutionally and ideologically circumscribed. The peculiarly American commitment to standardized, quantified and privately administered intelligence testing has taken root in this context as an objective, "scientific" instrument for sorting and classifying citizens — yet one which, given its power to produce inequality, remains essentially contested.

How the authority of science conflicts with or warrants other forms of authority, particularly the authority to govern at times of pronounced social change, is the central theme of the three remaining chapters; in these studies, co-production comes into focus as different forms of authority are constituted, embodied, challenged and restabilized. Peter Dear reflects on the interdependence of civil and epistemological authority in seventeenth-century Europe, as natural philosophers wrestled with the sources of legitimate expertise. The political theory underpinning absolutist ideologies of "mystery of state" applied, he suggests, to the establishment of knowledge-claims made through new kinds of experimental procedures resting on observations of nature. The credibility of such demonstrations could not be fully broken down into reasons, or analyzable components, that did not depend, at some irreducible core, on the reliability of the experimenter. For experimental results to be authoritative, experts thus needed recourse to some shared domain of unquestioned moral authority where

further explanation was no longer felt to be necessary. In early modernity, Dear proposes, the rituals of absolute monarchy, including display to aristocratic audiences, provided natural philosophers with one such resource for establishing their own claims of transcendent expertise.

Michael Dennis' chapter focuses on the postwar confrontation in the United States between a science profoundly dependent on military funding and the state's defensive interests and the vision of science entertained by Michael Polanyi (1962) and others as an autonomous republic of free-thinking citizens. Yannevar Bush, a contemporary of Robert Oppenheimer and key presidential science adviser, embodies the precarious effort to resolve these contradictions. Dennis' portrayal of Bush uses a suggestive image — Bush's head surrounded by a crown of destructive weaponry — to symbolize the unresolved tensions between the sin of overdependence on a military agenda and redemption, through basic research, in postwar American science. Although Bush is widely identified as the chief architect of the National Science Foundation and author of American society's "contract with science", he is here revealed as a tragic figure, unable to rein in the momentum of militarization and state patronage unleashed by the war. In a personal defeat, this relic of an earlier, more gentlemanly era of independent expertise is sidelined in the less civil, more resource-hungry order of knowledge and power that he did so much to bring into being.

Yaron Ezrahi's essay deals with the most fundamental kind of political crisis — a change in the very foundations of contemporary democracy. Departing from his earlier magisterial work on modern science as legitimator and model for liberal democratic politics (Ezrahi 1990), Ezrahi notes that in today's world the representations of reality produced by science, and shared by a democratic citizenry, fight for space in the public mind with the onrush of images created and disseminated worldwide by the mass media. In contrast to the esoteric knowledge and information produced at great expense by science, media representations, which Ezrahi suggestively calls "outformations", are generally much more accessible to publics. They require less time, effort, knowledge and skills to interpret than does the information generated by science. However expensive they are to produce, media representations, once created, can be accessed by widely dispersed consumers and publics at relatively little additional cost. Media representations also contravene some of the most basic assumptions of scientific reality: that emotion, ambiguity, subjectivity and the inner self have to be bounded out of the space in which we perceive what is truly real. In these respects, they are more appealing to ordinary citizens. Increasingly, Ezrahi argues, the relatively high-cost, high-entry-barrier reality of science has had to distance itself from everyday human experience; lower-cost, more accessible media realities to some extent fill the imaginative void left by the retreat of science. Like other authors in this collection, Ezrahi is careful to note that he is not describing the overthrow of a hegemonic Enlightenment tradition by one that is equally totalizing in its fragmentation of human perceptions. What he describes is far more an emergence of competing claims on the democratic

Note

1 Yeats ends the sonnet, which describes Leda's ravishing by the swan Zeus, with the couplet:

Did she put on his knowledge with his power
Before the indifferent beak could let her drop?

(Yeats 1956)

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The idiom of co-production, as we have argued in this volume, represents a major synthesis of scholarship in science and technology studies (S&TS). At once capturing and helping to crystallize shared orientations from a broad cross-section of the field, this interpretive framework illuminates how cognitive understandings of the world we live in are tied at many points to social means of intervening in or coping with that world. The concept of co-production thus rejects the simplifications of both social determinism and scientific or technological determinism; it sees science neither as constituted by interests alone nor as an unmediated reflection of nature. On the contrary, it presumes that knowledge and its material embodiments are products of social work and, at the same time, constitutive of forms of social life. It acknowledges that lived "reality" is made up of complex linkages among the cognitive, the material, the normative and the social – and that understanding these links is indispensable to meaningful projects of social theory and prescriptive analysis. For all these reasons, co-production offers as much traction in explicating the social dimensions of scientific and technological change as in exploring the cognitive and material bases of other powerful political and cultural configurations.

We have seen that co-productionist literature in S&TS engages with questions that are broadly speaking both metaphysical and epistemological – that is, both about the way the world is and how we find out about it. I have called the former type of work *constitutive*, because it speaks to the creation of fundamental ordering devices and categories; I have called the latter type *interactional*, because it deals with the conflicts and accommodations that arise when competing natural and social orders are brought into confrontation. In either case, what distinguishes co-productionist analysis from conventional metaphysical or epistemological inquiry is its constant rejection of *a priori* demarcations. Indeed, co-production blurs the very distinction between metaphysics and epistemology, showing how our knowledge of things as they are relates to earlier choices about how we wish to know things in the first place. Neither the existence of things nor our knowledge of them can be taken for granted in this framework. Rather, the object is to illuminate how particular states of knowledge come into being, what makes them persist or disappear, and how they shape and are shaped by people's deeper political and cultural, as well as cognitive and material commitments.

In this concluding chapter, I pull together the volume's principal themes by highlighting again the four objectives we hope to serve by adding co-production to the conceptual repertoire of the social sciences. These are description, explanation, normative analysis, and prediction – this last as a possible spur to social action and change. Under each heading, the contributors to this volume have shown that the idiom of co-production usefully supplements the insights derived from traditional social science disciplines. It problematizes categories that have been taken as foundational in other analytic programs – such as macro and micro, structure and agency, state and society – but it also shows how questioning such categories can lead to systematic lines of inquiry rather than to conceptual confusion. In particular, the idiom of co-production can be usefully deployed, as we have seen, whenever knowledge is incorporated into identities, institutions, discourses and representations. These four terms are in some sense fundamental to all current social thought; co-production simply offers different, and generative, ways of characterizing their nature, structure, effects and boundaries.

Yet, expansive though this framework is, co-production remains only one possible way to account for the relations of science, technology and society. It aims neither to be a universal grand theory, nor to be univocal in the sense of commanding all who adopt this perspective to invoke it in precisely the same ways, using the same units of analysis, and with the same interpretive or critical intent. Working in the co-productionist idiom, in short, requires not only attention to its possibilities but also modesty about its limits.

Description: science in society, society in science

Like science itself, theories of scientific change once tended to extract their object of investigation from contamination by "the social". The resulting austere vision of science – as driven more by logic than interests and more by personal inspiration than political economy – has long since been set aside in favor of richer accounts that stress the multiple human commitments involved in the production and application of knowledge. Social histories of science and technology have become commonplace, as have, since the pathbreaking work of anthropologists and sociologists of science in the 1970s (Latour and Woolgar 1979; Bloor 1976), studies focusing on the construction of knowledge through human agency, instruments and will. The theme of co-production can be seen as a productive extension of this trend. If early sociologists of science were concerned principally with bringing the social back into knowledge-making, a new generation of S&TS scholars has acknowledged the need to explore, in a fully symmetrical move, the playing out of systems of knowledge and technology within society. The co-productionist framework, as elaborated in this volume, crucially furthers this move.

The birth of S&TS as a field is often dated to the publication of Thomas Kuhn's (1962) *The Structure of Scientific Revolutions* or, by the field's own cognoscenti, to the still earlier work of Ludwik Fleck (1979 [1935]), who, in

attributing the development of the Wassermann test for syphilis to a "thought collective", provided a crucial precursor for Kuhn's notions of scientific paradigms and normal science. Yet Kuhn was not a co-productionist in the sense proposed by the contributors to this volume. As Ian Hacking has perceptively observed, Kuhn saw himself as an internalist historian of science, and for all that he "emphasized a disciplinary matrix of one hundred or so researchers, or the role of exemplars in science teaching, imitation, and practice, he had virtually nothing to say about social interaction" (Hacking 1999: 43). But like a river gathering flood from many tributaries on its way to the sea, a later generation of S&TS scholarship has acquired depth and force from fields that *do* take social interaction as their primary concern. Today, S&TS draws inspiration as much from ethnography, law, cultural studies and feminist theory as it does from intellectual history or studies of particular technoscientific systems. The emergence of co-production as a powerful analytic lens reflects this intersection and cross-fertilization of perspectives.

Co-production insists on contextualization. Since Clifford Geertz (1973: 5-10) introduced the term "thick description" into everyday academic discourse, it has become clear that attention to context is a prime methodological principle of interpretive work in the social sciences. Some fields, such as social and cultural history, never denied the need to understand phenomena in their contexts, but many areas of the social sciences – especially those centered on scientific images of humans as predictable, calculating agents – have modeled behavior as obeying law-like regularities, independent of politics, culture, time or place. By contrast, work in the co-productionist idiom sees knowledge practices as firmly "situated" (Haraway 1991: 183-201) – yet with permeable boundaries that not only allow contextual factors to seep in and mold the production of science and technology, but also, and equally, enable scientific and technological achievements to loop back and reorder the organization and self-perception of society.

For all these reasons, there is considerable descriptive richness to be gained from the co-productionist approach, a claim amply supported by the chapters in this volume. Whether in the work of international bodies (Miller, Thompson, Storey, Waterton and Wynne) and specialist professional communities (Rabeharisoa and Callon, Hilgartner, Lynch), or in the political work of scientists or experts and the state (Carson, Dear, Dennis, Ezrahi), the co-productionist vision illuminates the thickness of connections between what we know and how we know it. Constitutive studies have sharpened our sensitivity to new and emergent sociotechnical phenomena, while work in the interactional mode has alerted us to subtle cognitive differences between and among competing social orders.

Co-productionist analysis, as repeatedly documented in the foregoing chapters, shifts our attention from *fact-making* (the traditional preserve of much work in science studies) to *sense-making* as a topic of overarching interest, with scientific sense-making as a particular, if highly significant, subcategory. It brings society's collective habits of interpreting and ordering experience within the perimeter of scholarly inquiry. As a result, our questions about the social world

start changing: we ask how states see (Scott 1998), how institutions think (Douglas 1986), how the law knows (Jasanoff 1995), how cultures reason (Sahlins 1995), and how societies grapple with risk (Beck 1992). Significantly, questions like these promise to bring S&TS scholarship into more fruitful conversation with traditions in the disciplinary social sciences that have grappled with similar questions about institutionalized knowledge and its relations to power.

Explanation: against linearity

Co-productionist accounts advance the goal of explanation in several ways which the foregoing chapters have brought into sharper focus. First, even more than other S&TS concepts, co-production is starkly opposed to linear and monocausal stories about scientific, technological or social progress. Constantly highlighting the contexts in which events occur, and which they in turn remake, these stories promote more complex forms of accounting in which causes and effects are braided together in strands that resist artificial separation into dependent and independent variables. Such narratives make simple explanations for most phenomena harder to sustain. In compensation, they open up questions, and offer at least partial enlightenment, in areas that could not readily be fitted to conventional understandings of cause and effect. Put differently, by rejecting linearity, co-production stories undoubtedly complicate the "why" questions that have formed the staple of much social science research; at the same time, they add to the agenda of the social sciences a series of "how" questions that either have eluded systematic inquiry or else were rendered invisible by existing disciplinary framings.

Further, the chapters in this volume demonstrate the fertility of the co-production framework in bringing new objects and developments before the S&TS analyst's gaze. As we have repeatedly observed, this approach is particularly useful in making sense of emergent phenomena. It shows how certain conceptual designs and cognitive formulations gain ground at the expense of others, and how, once adopted, these successful settlements come to be seen as natural, inevitable or determined in advance. Importantly, co-productionist accounts display the specific mechanisms by which such erasures occur; mechanisms that routinely involve the production or reconstitution of scientific and technical knowledge. Thus Carson explains how "intelligence" became a marker of American citizens, but not of their comparably endowed French counterparts, producing in consequence different "human kinds" (Hacking 1999) on the two sides of the Atlantic. That Americans measure this quality of intelligence with a test originally developed in France only makes the result the more piquant. National and supra-national identities – such as being European, African, global or imperial – take shape, in part, through the activities of knowledge-making bodies in chapters by Waterton and Wynne, Thompson, Miller, and Storey. These authors show the contingent and contested character of such emergent identities, and the impossibility of stabilizing them without recourse to institutionalized ways of knowing. On a different scale, Hilgartner shows how ideas of property,

and associated norms of what counts as public or private, are unexpectedly, almost invisibly, renegotiated in the daily transactions of genome scientists.

Other chapters offer explanations for problems that arguably only come into distinct view through the lens of co-production. These are questions that arise when we explicitly inquire into the social arrangements that prop up particular natural orders or, in reverse, the epistemologies that help to sustain particular social orders. How, for example, did experimentally grounded knowledge acquire unchallenged authority in the seventeenth century, even though the personal testimony of the experimenter was always vulnerable to skeptical questioning (Dear)? How did a perception of the weather as consisting of local temperature and precipitation patterns yield to a view of the climate as a unified global phenomenon affecting the entire planet (Miller)? How have the identity of the "research subject" and related research practices changed as genetics-based biomedicine produces new kinds of relationships between investigators and patients (Rabcharisova and Callon)? How do mundane aspects of legal procedure constitute, but also validate, the identity of experts and the nature of expertise (Lynch)? What work did the concept of "basic science" do in the postwar discourse of American science policy, and how did it help cement a new ordering of science and the state (Dennis)? And how has the pervasive influence of the mass media affected civic epistemologies, altering the perceptions and standards of reality by which democratic politics make their collective choices (Erzahi)?

We note that nothing in the formulation of these questions renders them in principle inaccessible to historical, sociological or political inquiry. As a practical matter, however, questions like these only began to surface when S&TS scholars thought to look at social and scientific change from the standpoint of co-production, asking how each kind of transformation implicates and influences the other. For the most part, the disciplinary social sciences still unquestioningly accept the boundary between nature and society as given. Questions that assume the hybridity of these domains as a starting premise do not easily arise in such contexts. Once they are on the table, moreover, they may require a blending of concepts and methods that feels particularly comfortable to researchers in S&TS.

Normativity: erasures and alternatives

Co-productionist accounts, as already noted, permit us to regain access to the political and cultural histories of facts and artifacts; in this sense, they facilitate not only interpretation but also critique. The possibility of critical engagement is perhaps most apparent when a co-productionist eye is brought to the analysis of emerging orders. It is at the point of emergence, before things are completely stabilized or black-boxed, that one most easily observes the mutual uptake of the social and the natural. It is also at this moment of flux that processes of co-production are most influential in setting the stage for future human development. Important normative choices get made during the phase

of emergence: in the resolution of conflicts; the classification of scientific and social objects; the standardization of technological practices; and the uptake of knowledge in different cultural contexts. Once the resulting settlements are normalized (social order) or naturalized (natural order), it becomes difficult to rediscover the contested assumptions that were freely in play before stability was effected.

Many of the preceding chapters set out in detail what is at stake in bringing new forms of cognitive and social life into being – and how, through institutional means, such conflicts are eventually resolved, or at least rendered unthreatening (see, in particular, Miller, Storey, Waterton and Wynne, Dennis). Working through one example may help to clarify the point. In their history of the European Environment Agency (EEA), Waterton and Wynne showed how practices of producing objective, policy-relevant information worked as surrogates for different models of European integration: first, a model of Europe as homogeneous, centralized, and capable of full-blown harmonization by official policy institutions; second, a much more chaotic and bottom-up Europe, in which information provision is more a matter of strategically highlighting ignorance, and thereby creating different, situated possibilities for citizen intervention. A strength of these authors' analysis is that they do not force closure on the imagination of Europe any more than the EEC, the chief actor in their story, is able to do. Rather, we are left with a sense of different, co-existing, normatively loaded *ideas* of Europe, whose institutions of knowledge-making emerge as important, and meaningful, sites of political identity-building. In short, Waterton and Wynne restore the most fundamental kind of politics – decisions about what kind of policy to be or to become – to a sphere of technical decisionmaking from which politics has tended to be leached away in most high-modern theorizing about expertise.

Co-production is also helpful as a framework within which to make sense of persistent differences in the way societies define or cope with "the same" phenomenon, be it human intelligence (Carson), endangered species (Thompson) or climate change (Miller). By accounting for the multiple ways in which knowledge becomes embedded in institutions, practices, norms and material objects, this way of looking at order demonstrates how cultural discrepancies in knowledge/power relations arise and can be sustained over long periods of time. Such divergent settlements in different cultural and political contexts can become a source of potentially serious conflicts and misunderstanding. In turn, illuminating the reasons for divergence holds out hope for cooperative behavior or, at the limit, deliberated cultural autonomy – as in Thompson's on the whole optimistic account of African elephant management, in which an undemocratic universalist regime of species protection was replaced by a more locally diversified, context-sensitive approach.

Most generally, co-productionist accounts add to existing theories of power, refining our understanding of what power means, and how it is formed and exercised. That knowledge is a form of power is not, of course, any longer a new idea in either social theory or S&TS, nor does it come as a shock that institutions

exercise power through specific knowledge-making practices that form and constrain human subjectivities. Yet there are several ways in which the idiom of co-production inflects and accentuates these general propositions. First, it simply provides a constant reminder that, not only does knowledge constitute power, but equally power frames and organizes knowledge; hence, wherever power originates or is concentrated, one should also look for its expression through knowledge. As in Yeats' famous sonnet, *Leda and the Swan*,¹ power and knowledge come coupled, and one can therefore always ask how the exercise of the one relates to the formation and uptake of the other. Second, the concept of co-production alerts us to the fact that power is constituted as much through the elision of marginalized alternatives as through the positive adoption of dominant viewpoints. Strategic silences, no less than sites of explicit articulation, hence are grist for the mill of co-production. Third, co-productionist analysis is symmetrically concerned with both stability and instability: thus not only the radical paradigm shift (Kuhn 1962) but also the long-term persistence of cultural and political formations calls for intellectual engagement in this framework. In this respect, co-production sees the very taken-for-grantedness of entrenched power structures as a spur to further inquiry.

Prediction, prescription and action

Co-production, we have argued, sacrifices simplicity for richness and linearity for deeper contextualization. So conceived, this approach is more consistent with projects of interpretation than intervention. Co-productionist accounts may be historical or ethnographic or comparative; their ambition is rarely predictive or prescriptive on the model of the policy sciences or economics. Such studies are better suited to explaining how things came to be ordered in particular ways than at forecasting the future impacts of specific choices and decisions. And yet, as we have also suggested, co-production can yield predictive insights in some circumstances – for example, by pointing out deep cultural regularities in knowledge-making and use; by displaying the basis of institutionalized ways of knowing; by explaining what is likely to be at stake in particular identities or representations; or by showing how technical discourses may impose systematic frames of meaning on events that might otherwise seem random. In short, the co-productionist perspective is predictive in something like the way good history is predictive: it may not be a reliable guide to exactly how things will play out the next day or the next year; yet, without its benefits, societies may be doomed to repeating the same mistakes, using and reusing the same epistemological binders.

There is, however, a different and more reflexive point to be made about the implications of the co-productionist framework for social action and change. For if, after all, this theoretical orientation makes sense today, then the very fact of inserting such a perspective into the world should loop back, in Hacking's (1999) terms, and reorganize to some degree the way we think about the relations of knowledge, power and culture. Are there signs that co-production – itself a

constitutive, historically situated, cognitive frame – is having this kind of influence in the world? Is it only an analyst's category or is it also playing a role, in however limited a fashion, as an actor's category, and, if the latter, then for which types of actors? These questions are worth exploring in greater detail than is possible in this brief conclusion, but one or two straws in the wind may be cited from the earlier chapters.

Both Waterton and Wynne and Rabeharisoa and Callon offer case studies that can be seen as bridging the gap between co-production as an analytic approach and co-production as a strategic instrument in the hands of knowledgeable social actors. In the former case, it is the European Environment Agency that to some extent self-consciously directs its knowledge-making practices toward realizing a political vision of Europe. By interpreting notions of objectivity and policy-relevance in particular ways, the EEA has arguably opened the door to new forms of engagement between European citizens and the European policy apparatus. Though threatening to the authority of Brussels in the short run, this openness may prove beneficial for a vastly enlarged Europe whose politics may be increasingly resistant to strict homogenization and top-down, central control.

In the latter case, Rabeharisoa and Callon show how the French muscular dystrophy association has taken a variety of steps, from data gathering to creating a new discourse of patient engagement, in order to facilitate non-traditional relationships among patients, their families and the biomedical establishment. At stake is the very definition of the research subject, a role formerly seen as passive and inept, but redefined in this case to permit the possessors of subjective knowledge of a disease to participate on something like an equal footing with those possessing objective knowledge of their condition. "Lay" patients and "trained" experts thus find themselves on an epistemologically leveled playing field, each now recognized as a knowledge-bearer with the capacity to participate in new cooperative forms of medical research and development.

Under what conditions do such strategic uses of co-production become imaginable? Perhaps it takes a threat of life-and-death proportions. It may be no accident that the stakes for both the EEA and the muscular dystrophy association were exceptionally high – nothing less than existence itself. The EEA was struggling to establish itself as a relevant actor, with the autonomy to shape its mission independently of Brussels. The French patients and their families were coping with a debilitating disease for which there was no cure in sight. Under such extreme pressures, it may become easier to be more instrumental, if not more reflexive, about all of one's resources and faculties, including those of knowledge-making. For the rest, most of the actors in the foregoing chapters seem to perform the scripts of co-production without consciously taking on board their transformative potential. But let us be forewarned: this, too, may be only a passing state of knowledge. Careful readers of this book, at any rate, will surely come away thinking differently about the relations between knowledge and power, and of their own capacity to intervene strategically – and we can only hope for the good – in that ever more important relationship.