Informationalising Matter

Systems Understandings of the Nanoscale[1]

Matthew Kearnes[*]

Mastery

Themes of mastery, domination and power are familiar to any scholar of modern technology. Science is commonly cast as enabling the technological control over both the natural and physical worlds. Indeed, Francis Bacon famously equated scientific knowledge with power itself—stating that 'knowledge itself is a power' (Bacon in Montagu 1825, 71). Bacon's now ubiquitous phrase—commonly repeated as the banal 'knowledge is power'—was an attempt to combat three heresies in scriptural interpretation by asserting the conjunction between biblical knowledge and divine power. Opening his critique of the heresies he states: 'You err, not knowing the scriptures nor the power of God'. In this sense the equation made between knowledge and power is of cosmic significance for Bacon in that knowledge is fundamentally associated with divine power. This image of scientific knowledge, method and rationality is deeply seductive. In this Baconian mode scientific method is irreducibly associated with human mastery over natural systems and the material world. In this image science and technology are defined as a kind of power *over* the physical world—the power of knowledge, method and the logos over nature, myth and irrationality (Winner 1978). In its original Latin sense—*ipsa scientia potestās est*—the word that translates in English as simply power is a in fact a specific type of power. *Potestās* is defined as 'power over'—with particular resonances with political and juridical traditions in Roman law. That is,

---

knowledge is equated not simply with personal capacity. Rather, knowledge produces the power of mastery, domination and coercion.

Not only does Bacon's iconic proposition form the ontological basis of both industrial society (Farrington 1951) and the techno-colonial project of nation building (Nye 1994), in which scientific rationality increasingly dominates the Hobbesian character of 'natural' existence, but this image of science is also central to contemporary understandings of the capacities of technology. For example, the hubris that surrounds the emergence of new technological domains such as nanotechnology, synthetic biology, neuroscience and the promised convergence between these domains perpetuates this image of scientific endeavour through the circulation of common claims that such technologies will be the cure for all human ills and enable the production of almost anything 'from the bottom up' (Kearnes et al. 2006). Though often represented as a new type of science based on new techniques for the manipulation of matter at the nanoscale, some authors have highlighted that the notions of mastery and control central to nanotechnology are possibly best understood as a modern variant on a very old definition of science. The notions of material abundance that populate the nanoworld, particularly notions of creating new materials 'from scratch', have clear links to medieval notions of alchemy, and the promise of creating the valuable from the ignoble (Yonas and Picraux 2000). More broadly on the theme of control, Dupuy and Grinbaum suggest that nanotechnologists will inevitably 'set off processes upon which they have no control' such that 'the sorcerer's apprentice myth must be updated: it is neither by error nor by terror that Man will be dispossessed of his own creations but by design' (2006, 292). Nanotechnology is associated with the promise of technological abundance based on the precise mastery and control of natural and chemical systems—such that the disparate range of practices classed as nanotechnology are increasingly defined by a broad programme of 'controlling the structure of matter'.[2]

The definition of science and technology as a kind of 'power over' is also central to a range of counter-narratives—those of technological failure, accident and loss of control. Jonas suggests that 'the other side of the triumphal advance [of science] has begun to show its face, disturbing the euphoria of success with threats that are as novel as its welcome fruits' (1985, ix). For many commentators, the emergence of this mirror image of science suggests that the power of science has become autonomous from human intention, leading to consequences that are potentially beyond human imagination and control (Ellul 1964; Heidegger 1977; Jonas 1985; Winner 1978).

This logic of mastery is figured in post-Heideggarian philosophies of technology as almost the defining feature of the technical. Technology is defined by the rationality of this 'power over' both the human and the nonhuman.

---

[2] This is most obviously apparent in the early hubristic accounts of the possibilities of nanoscale research. See, for example, Crandall (1996) and Dinkelacker (2002).

Famously Heidegger (1977) defines modern technology as a kind of 'enframing' of both the human and nonhuman by a technical rationality. For Heidegger:

> Technics commands nature … Nature is consigned by technics; nature has become the assistant, the auxiliary; in a similar fashion it is exploited by technics which has become the master. (Stiegler 1998, 24)

Ellul furthers this definition, speaking of a 'mechanisation in itself' defined by 'the application of [technique] to *all* domains hitherto foreign to the machine' (1964, 7; emphasis in original). Even Latour's (1993) rejoinder that 'we have never been modern' assumes a definition of modernity as an opposition between technoscientific rationality and nature. Though for Latour the separation between rationality and primordial nature has never been thoroughly achieved, his critique of the modernist project is a critique of the pretensions of *potestās*, arguing for a more materially situated analysis of attempts to generate this form of 'power over'.

Power

In the context of this one-dimensional understanding of the nature of power as 'power over' Negri (1991) introduces an alternative conception of the nature of power. Drawing on Spinoza, Negri offers a distinction between *P*ower as *potestās* and *p*ower as *potentia.* Whereas *potestās* 'denotes the centralized, mediating, transcendental force of commands', *potentia* 'is the local, immediate, actual force of constitution' (Hardt in Negri 1991, xiii).[3] For Negri *potentia* is an entirely different concept of power. The power of mastery and command is replaced in Negri's analysis of Spinozian conceptions of ethics and democracy by a neo-vitalist definition of power as potential or force. For Negri 'Power over' is challenged by this unfolding notion of 'power to' (Lash 2007).

The philosopher Gilles Deleuze similarly suggests that the notion of 'control' has come to define the modern exercise of power. His provocation is that we have entered what he terms 'control societies'. He suggests that 'We're in the midst of a general breakdown of all sites of confinement—prisons, hospitals, factories, schools, the family … Control societies are taking over from disciplinary societies' (Deleuze 1990, 178). Control operates for Deleuze in the same way the notion of the episteme operates for Foucault, defining the 'limits of the thinkable' (Connolly 1985) such that control rather than discipline becomes, for Deleuze, a central figure around which modern life and contemporary societies are constituted. In defining the characteristics of power and the emergence of control societies, Deleuze makes no distinction between political and 'natural' forms of power, nor does he distinguish political power from technoscientifically

---

[3] See also Lazzarato (2002), Ricken (2006) and Röttgers (1990) who consider the distinction between power as pouvoir and puissance in French and macht and vermögen in German.

enabled capacities—power over the material world, for example. Rather, power is defined as relations of force exercised and experienced by both human and nonhuman bodies. In contrast to traditional political philosophy, which posits an ontological distinction between forms of political power and physical and material capacities, Deleuze's immanent philosophy posits simply the constitutive capacity of force. Employing and redefining both Nietzsche's notion of the will to power and Spinoza's notion of the body, Deleuze defines reality as 'a field of quanta and quantities of force' (Patton 2000, 52) such that:

> Every relationship of forces constitutes a body—whether it is chemical, biological, social or political. Any two forces, being unequal, constitute a body as soon as they enter into a relationship. This is why the body is always the fruit of chance. (Deleuze 1983, 37)

The equivalence that Deleuze grants to 'relations of force' in his definition of power suggests that his broader provocation that modernity is witnessing the emergence of control societies is not simply embodied in controlling political techniques or technologies.

Negri's characterisation of the nature of Power, his articulation of an alternative conception of power as *potentia* and the Deleuzian notion of the emergence of 'control societies' characterised by more distributed forms of power highlight the simultaneous modalities of power inherent in technoscientific knowledge. This is particularly evident in the ways in which nanoscience and nanotechnology are defined by notions of control—and particularly the emergence of more distributed, vitalistic understandings of control—which increasingly do not rely on direct physical manipulation. Whilst nanotechnology is rhetorically defined by a broad project of 'controlling the structure of matter, as Bensaude-Vincent (2006) demonstrates, nanoscientific practice is populated by two distinct models of material control. Whilst notions of direct physical control of nanoscale components is informed by a post-Baconian understanding of both knowledge and power, more distributed versions of control based on the 'modulation' of biological or chemical processes rather than their direct manipulation are emerging in a range of current fields of technoscientific development.[4] At issue here is not to defend one version of power over another (as Negri does), but to explore the way in which we see in nanotechnology two simultaneous notions of power evident in notions of control. Here I offer a modest analysis of the emergence of distributed, systems based notions of control, and speculate on the implications of this analysis for ethics and democracy.

---

[4] For example in neuroscience (Rose 1996; 2005), development and systems biology (Oyama 2000a; b) and in nanotechnology (Jones 2004; Laughlin 2005).

Control

The vision of nanotechnology as both enabling and depending upon the precise control over the structure of matter is best exemplified by the following claim by the former HP researcher Jamie Dinkelacker: 'Total (or near total) control over the structure of matter will intrinsically revolutionise our lives. No aspect of our daily living—let alone other technologies—will remain untouched' (2000, 2). This phrase—'control over the structure of matter'—is a symbol of the sheer promise and transformative possibility of nanotechnology. Despite its obviously hyperbolic tone, the imperative to gain such control has become a paradigmatic goal for much nanotechnology research. This goal has become *the* default objective for current nanoscale research with the associated promise of wider socially transformative innovations (Kearnes 2006; Kearnes et al. 2006). The key terms for notions of control in contemporary experimental practice are 'precision' and 'accuracy' that enable the tailoring of chemical or biological systems to human-derived 'functions'. Control therefore represents a technoscientific orientation to research that has become the dominant model for scientific practice (Nowotny et al. 1994).

However, it is clear that such notions of control are not unique to nanotechnology. Rather, visions of control—particularly the possibilities for precisely controlling the chemical and biological fabric of life—circulate through a range of contemporary technoscientific research programmes. The now infamous claim that nanotechnology will enable 'programmable matter' or 'desktop replication' (Drexler 1986; Gershenfeld 2005; Kurzeil 2005) draws on an analogous repertoire of rhetorical concepts and metaphors. For example, Ian Wilmut, the well known embryologist who played a crucial role in the team that in 1996 first cloned a mammal—the now ubiquitous lamb named Dolly—has recently announced the arrival of the 'age of biological control' (Wilmut 1999; Wilmut et al. 2000). Wilmut reverses the relationship between the biological and the social—in which biology is cast as the base upon which social structure is later constructed—suggesting control over biology will be possible through technologies such as nuclear transfer and cloning. Together with colleagues he states that:

> In the 21st century and beyond, human ambition will be bound only by the laws of physics, the rules of logic, and our descendents' own sense of right and wrong. Truly Dolly has taken us into the age of biological control. (Wilmut et al. 2000, 17)[5]

For Wilmut and his colleagues, techniques such as nuclear transfer and cloning mean that there will be now no 'biological' limitation on human

---

[5] See also Franklin's (2001) analysis of Wilmut's pronouncement.

ambition. As such, the age of biological control is characterised by the incorporation of human intentionality into biological systems such that *anything* becomes literally possible. Wilmut and his colleagues suggest that the only possible limitations on human ambition and intention are the more basic rules of physics and logic and the self-imposed limitations of ethics and moral sentiment. Additionally, themes of knowledge and control have been recently redeployed in imaging possible convergences between nanotechnology and biology, and the potential for 'making life from scratch'. In a recent statement on synthetic biology McEuen and Dekker, representing the Kavli Institute of Nanoscience,[6] suggest that:

> Biologists dream of controlling the machinery of life like engineers control device layouts on a computer chip, and engineers dream of evolving adaptive architectures that can, among other things, build themselves. What will happen as these two worlds collide? … Synthetic biology is the code name for engineering using the machinery of the cell, from tinkering with existing organisms all the way to the design of life from scratch. The idea is pretty radical: in the past 50 years we engineered in silicon; now we will engineer in life. (McEuen and Dekker 2008, 10-11)

It is in this context of a proliferation of discourses of technologically enabled control and escape from biological and physical limitations that nanotechnology is presented as potentially enabling the shaping of the world atom-by-atom by imagining a new field almost 'beyond physics'.

Information

How then do we understand ways in which notions of control—and the imagined uncoupling of human capacity from natural and physical limitations—have proliferated in the emergence of recent technoscientific projects? In what remains I suggest that what links these different notions of control is a reconceptualisation of biological life and physical and chemical systems as *informational.* I suggest that the notion of control emerges as a technoscientific paradigm as biological and chemical processes are conceived as communicative systems. Here we see the recent proliferation of systems metaphors—chemical *systems*, biological *systems*, social *systems*—which have the effect of making ubiquitous a range of informational metaphors in the definition of almost all that is. Secondly, I suggest that almost independently of the proliferation of such informational metaphors, we are witnessing in new technoscientific programmes such as nanotechnology a parallel conviction that the physical world can be manipulated *as if it were* information.

---

[6]http://www.tnw.tudelft.nl/live/pagina.jsp?id=baabfe7e-0bc8-4118-9f4e-afc81cca95c7&lang=en

There is a clear lineage here to Jean-Pierre Dupuy's (2000) analysis of the two 'convictions' that were central in shaping the development of cybernetics, which are of broader relevance across the range of emerging fields of technoscientific research. He identifies the first conviction with the notion that thinking is conceived as a 'form of computation' in which:

> The computation involved is not the mental operation of a human being who manipulates symbols in applying rules, such as those of addition or multiplication; instead it is what a particular class of machines do—machines technically referred to as 'algorithms'. By virtue of this, thinking comes within the domain of the mechanical. (Dupuy 2000, 3)

The second conviction that Dupuy identifies as shaping the development of cybernetics is the notion that 'physical laws can explain why and how nature appears to us to contain meaning, finality, directionality, and intentionality' (2000, 4). For Dupuy, this combination of a physicalist theory of the mind and the conception of human cognitive capacities as a form of machine-like computing acted as 'articles of faith' for the founders of the cybernetic movement. The key terms in this cybernetic definition of human life are 'information' and 'control'. For example, Weiner's (1961) account of systems theory implicitly links information theory to control, positing cybernetics as the science of 'control and communication in the animal and machine'. The key problematic in information and communication theory - which were direct inheritors of WWII military research—was the problem of control—how to control both the quantity and movement of information (Shannon 1948). Indeed, Hughes and Hughes (2000) trace the influence of operations and systems research that emerged out of war-time military research and became a powerful heuristic in 'systems definitions' of both natural and social systems. The success of systems research—with its emphasis on information and control—was its increasing use in civil applications—particularly in governmental and planning theory (Deutsch 1963; Taylor 2005). Writing on the development of molecular biology, Keller (1991) identifies three similar 'critical shifts in twentieth-century biology' that both contribute and are attributable to the emergence of molecular biology as a new research domain after the Second World War. The first two of these discursive and ontological shifts closely relate to those identified by Dupuy. Firstly, she argues that whilst in the history of biology the 'essence of life' had traditionally been located in the physical and chemical constitution of the organism, the emergence of molecular biology is associated with a more reductive definition of life as genetically determined. This first shift operates as the parallel to the physicalist theories of the mind that emerged in cybernetics, artificial intelligence research and cognitive science, suggesting that human life might be explained materially in the physico-chemical constitution of DNA. The

second shift that Keller identifies is a redefinition of life through a set of linguistic and informational metaphors. Notions such that DNA operates as a 'code-script' have become an operational definition in experimental practice.

The significance of the proliferation of informational metaphors that originate in cybernetics and control theory and then structure the emergence of new fields such as molecular biology is twofold. Firstly, the proliferation and seeming ubiquity of informational metaphors has the effect of universalising understandings of physical, chemical and biological processes as systems. There is not the space here to develop an extended characterisation of the emergence of systems and communicative metaphors across contemporary science and technology except to note the increasingly mainstream conceptualisation of the referent object of nanoscience as a nano-system,[7] drawing on antecedent systems metaphors in chemistry, self-assembly and the information sciences (Lehn 2002; Whitesides and Grzybowski 2002). This has the effect of producing a communicative ontology in which all that 'is' is cast in informational terms. Secondly, this ontology is profoundly *techno*scientific in that it enables the secondary assumption that biological and physical life can be manipulated *as if it were* information. This notion that biological and chemical processes might be manipulated as if they were information is part of the wider cultural logic of information science. It is evidence of what Rosenberg terms the 'computer gestalt' that emerged out of developments in information science and cybernetics, in which 'the computer has become more than a tool or machine, it is a way a way of looking at the world' (1974, 264).[8]

In this coupling of systems understandings of the physical and natural world with this ambition to manipulate matter computationally, control emerges as the central doctrine of technoscientific power. Again there is a long genealogy to the emergence of notions of control in systems theory. Here I simply suggest that in systems conceptions of chemical and biological processes—and in particular the nanoscale—control emergences as a dominant trope for orienting technoscientific practice. Systems understandings require a new conception of power or physical capacity. Rather than directly manipulating matter, power 'works with' or seeks to control the operation and parameters of the system (Kearnes 2006). 'Power over' (*potestās*) is replaced by more contingent notions of control as 'power to' (*potentia*). This is increasingly the case, as Bensaude-Vincent (2006) suggests, given the growing significance of mimetic design paradigms in nanotechnology, which rely on distributed notions of control rather than straightforward mechanistic mastery.

Control Societies

What is remarkable about the centrality of notions of control in nanoscientific practice is the way they are mirrored in the social and political

---

[7] See for example Drexler's (1992) early account of nanotechnology as producing 'nanosystems' through 'molecular machinery, manufacturing, and computation'.

[8] See also Warner (2008).

construction of nanotechnology as a State-sponsored research programme. Consider for example, President Bill Clinton (2000) speech to the California Institute of Technology upon the announcement of the formation of the National Nanotechnology Initiative (NNI):

> Just imagine, materials with 10 times the strength of steel and only a fraction of the weight; shrinking all the information at the Library of Congress into a device the size of a sugar cube; detecting cancerous tumours that are only a few cells in size. Some of these research goals will take 20 or more years to achieve. But that is why there is such a critical role for the federal government. (President Clinton 2000)

Here Clinton invites the audience at Caltech to imagine 'shrinking all the information at the Library of Congress into a device the size of a sugar cube'. This passage clearly echoes—and indeed extends—Richard Feynman's original formulation of the possibility of writing the 'entire 24 volumes of the Encyclopaedia Britannica on the head of a pin' (1960, 22). As such, Clinton's speech positions nanotechnology as inheriting Feynman's now iconic ideas of 'manipulating and controlling things on a small scale'. The possibilities of control at the nanoscale are, for Clinton, irrevocably social in character heralding numerous possible breakthroughs. One might therefore point to the connection between notions of control in technoscientific practice and the ways in which contemporary fields are increasingly organised and structured through strategic research support mechanisms such as the National Nanotechnology Initiative. Notions of systems based control therefore are populated by a range of societal promises and expectations that constitute a profoundly post-Baconian conception of scientific knowledge. Rather than simply produce 'power' in the Baconian mode, contemporary nanoscience produces society itself.

This then is the significance of Deleuze's notion of control *societies*—the proposition that control is central to the very constitution of the social. Here we might distinguish contemporary systems-science from the what Foucault (1970) defines as a modern constellation of power and knowledge. In contrast to the increasing distributed nature of power in contemporary technoscience Foucault is interested in tracing the emergence of scientific disciplines and as such the emergence of the human subject as an object of knowledge. Rabinow, for example, demonstrates the way in which in Foucault's analysis of 'modern knowledge' we witness the emergence of 'man' or the 'anthropos' as the subject of knowledge:

> Foucault had gotten beyond structuralism and hermeneutics by showing how the historical relations of knowledge and power had produced an object of

knowledge that was also the subject of knowledge: Man.
(Rabinow 2003, 3)

If in the modern constellation of power and knowledge we witness the constitution of 'man' as the subject of knowledge, so the argument goes, we also are witnesses to the potential for technological intervention to threaten and challenge this very anthropos. As discussed above, the post-Heideggarian tradition in assessing the philosophical implications of technology follows this path, suggesting that the insidious ubiquity of the rationality of technics threatens the being of 'man' itself. This tradition of posing the problem of technology as a problem of 'man' has also had direct influence on the now institutionalised efforts to assess the 'ethical implications' of new technologies, which have tended to pose the problem of technology in terms of its consequences for the human subject. Perhaps, then, in attending to the emergence of more distributed notions of power inherent in systems-based understandings of nanoscale technoscientific practice and the wider emergence of 'control societies', this tradition needs to be re-thought. In particular, I suggest that in contemporary technoscience we witness the constitution of the social, rather than of 'man', such that control-based technoscience is irrevocably a social project. We must attend therefore to the broader societal dynamics of this image of contemporary science, thinking not simply of the ways in which technology challenges the anthropos, but additionally the ways in which the social is understood as a component of a technoscientific system itself. Rather than simply relying on a range of social promises in contemporary research fields, the social is conceptualised as part of the technoscientific project. Whilst nanotechnology is inherently social, the social in increasingly *nanotechnologised*—cast as a 'social-system' that enables rather than constrains nanoscale innovation (Nordmann and Schwarz 2009).[9] It is then not simply the socially transformative capacity of nanotechnology that requires critical attention, but rather that in the emergence of nanoscale research we are also witnessing the constitutions of new socialities (Rabinow 2005).

MATTHEW KEARNES
Department of Geography
Durham University
South Road, Durham
DH1 3LE
United Kingdom
m.b.kearnes@durham.ac.uk

---

[9] See Kearnes and Wynne (2007) on the politics of public enthusiasm.

References

Bensaude-Vincent, B. 2006. Two Cultures of Nanotechnology?. In *Nanotechnology Challenges: Implications for Philosophy, Ethics and Society*, eds. J. Schummer and D. Baird, 7-128. Singapore: World Scientific Publishing.

Clark, N. 1998. Materializing Informatics: From Dataprocessing to Molecular Engineering. *Information, Communication & Society* 1(1): 70-90.

Clinton, W. 2000. *President Clinton's Address to Caltech on Science and Technology*.
http://pr.caltech.edu/events/presidential_speech/pspeechtxt.html.

Connolly, W. E. 1985. Taylor, Foucault and Otherness. *Political Theory* 13(3): 365-76.

Crandall, B. C. ed. 1996. *Nanotechnology: Molecular Speculations on Global Abundance*. Cambridge, MA: MIT Press.

Deleuze, G. 1983. *Nietzsche and Philosophy*. London: Athlone Press.

Deleuze, G. 1990. Postscript on Control Societies. In *Negotiations - 1972-1990*, ed. G. Deleuze, 177-82. New York: Columbia University Press.

Deutsch, K. W. 1963. *The Nerves of Government: Models of Political Communication and Control*. London: Free Press of Glencoe.

Dinkelacker, J. 2002. *Transition to Tomorrow: Social Institutions at the Threshold of Nanotechnology's Molecular Epoch.*
http://sunarcher.org/jamie/pubs/Transition_To_Tomorrow_2002.pdf.

Drexler, K. E. 1986. *Engines of Creation: The Coming Era of Nanotechnology*. New York: Anchor Books.

Drexler, K. E. 1992. *Nanosystems: Molecular Machinery, Manufacturing, and Computation*. New York: John Wiley and Sons.

Dupuy, J. P. 2000. *The Mechanisation of the Mind: On the Origins of Cognitive Science*. Princeton: Princeton University Press.

Dupuy, J. P., and A. Grinbaum. 2006. Living with Uncertainty: Toward the Ongoing Normative Assessment of Nanotechnology. In *Nanotechnology Challenges: Implications for Philosophy, Ethics and Society*, eds. J. Schummer and D. Baird, 287-314. Singapore: World Scientific Publishing.

Ellul, J. 1964. *The Technological Society*. New York: Vintage Books.

Farrington, B. 1951. *Francis Bacon: Philosopher of Industrial Science*. London: Lawrence and Wishart.

Foucault, M. 1970. *The Order of Things: An Archaeology of the Human Sciences*. New York: Vintage Books.

Franklin, S. 2001. Culturing Biology: Cell Lines for the Second Millennium. *Health* 5(3): 335-54.

Gershenfeld, N. 2005. *Fab: The Coming Revolution on Your Desktop - From Personal Computers to Personal Fabrication*. New York: Basic Books.

Heidegger, M. 1977. *The Question Concerning Technology and Other Essays*. New York: Harper & Row.

Hughes, A. C., and T. P. Hughes, eds. 2000. *Systems, Experts and Computers: The Systems Approach in Management and Engineering, World War II and After*. Cambridge, MA: MIT Press.

Jonas, H. 1985. *The Imperative of Responsibility: In Search of an Ethics for the Technological Age*. Chicago: University of Chicago Press.

Jones, R. A. L. 2004. *Soft Machines: Nanotechnology and Life*. Oxford: Oxford University Press.

Kearnes, M., and Wynne, B. 2007. On Nanotechnology and Ambivalence: The Politics of Enthusiasm. *NanoEthics* 1(2): 131-42.

Kearnes, M. B. 2006. Chaos and Control: Nanotechnology and the Politics of Emergence. *Paragraph* 29(2): 57-80.

Kearnes, M. B., M. Macnaghten, and J. Wilsdon. 2006. *Governing at the Nanoscale: People, Policies and Emerging Technologies*. London: Demos.

Keller, E. F. 1991. Fractured Images of Science, Language and Power: A Postmodern Optic, or Just Bad Eyesight? *Poetics Today* 12(2): 227-43.

Kurzeil, R. 2005. *The Singularity is Near: When Humans Transcend Biology*. New York: Viking.

Lash, S. 2007. Power after Hegemony: Cultural Studies in Mutation?. *Theory, Culture & Society* 24(3): 55-78.

Latour, B. 1993. *We Have Never Been Modern*. Harlow: Pearson Education.

Laughlin, R. B. 2005. *A Different Universe: Reiventing Physics from the Bottom Down*. Cambridge, MA: Basic Books.

Lazzarato, M. 2002. *Puissance de L'Invention: La Psychologie Économique de Gabriel Tarde*. Paris: Le Seuil.

Lehn, J. M. 2002. Toward Complex Matter: Supramolecular Chemistry and Self-Organisation. *Proceedings of the National Academy of Sciences* 99(8): 4763-68.

Montagu, B., ed. 1825. *The Works of Francis Bacon*. London: Lord Chancellor of England, William Pickering.

Negri, A. 1991. *The Savage Anomaly: The Power of Spinoza's Metaphysics and Politics*. Minneapolis: University of Minnesota Press.

Nordmann, A., and A. E. and Schwarz. 2009. The Lure of the "Yes": Reflections on the Power of Technoscience. In *Governing Future Technologies: Nanotechnology and the Rise of an Assessment Regime (Sociology of the Sciences Yearbook), eds.* S. Maasen, M. Kaiser, M. Kurath and C. Rehmann-Sutter. Heidelberg: Springer (forthcoming).

Nowotny, H., M. Gibbons, C. Limoges, C., Schwartzman, P. Scott, and M. Trow. 1994. *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies*. London: SAGE.

Nye, D. E. 1994. *American Technological Sublime*. Cambridge, MA: MIT Press.

Oyama, S. 2000a. *Evolution's Eye: A Systems View of the Biology-Culture Divide*. Durham, NC: Duke University Press.

Oyama, S. 2000b. *The Ontogeny of Information: Developmental Systems and Evolution*. Durham, NC: Duke University Press.

Patton, P. 2000. *Deleuze and the Political*. London: Routledge.

Rabinow, P. 2003. *Anthropos Today: Reflections on Modern Equipment*. Princeton: Princeton University Press.

Rabinow, P. 2005. From Sociobiology to Biosociality: Artificiality and Enlightenment. In *Anthropologies of Modernity: Foucault, Governmentality and Life Politics*, ed. J. X. India, 181-93. Oxford: Blackwell.

Ricken, N. 2006. The Power of Power—Questions to Michel Foucault. *Educational Philosophy and Theory* 38(4): 541-60.

Rose, S. 1996. *The Chemistry of Life*. Harmondsworth: Penguin Books.

Rose, S. 2005. *The Future of the Brain: The Promise and Perils of Tomorrow's Neuroscience*. Oxford: Oxford University Press.

Röttgers, K. 1990. *Spuren der Macht: Begriffsgeschichte und Systematik.* Freiburg: Alber.

Shannon, C. E. 1948. A Mathematical Theory of Communication. *The Bell System Technical Journal* 27: 379-423, 623-56.

Stiegler, B. 1998. *Technics and Time 1: The Fault of Epimetheus*. Stanford: Stanford University Press.

Taylor, N. 2005. *Urban Planning Theory since 1945*. London: SAGE

Warner, J. 2008. Organs of the Human Brain, Created by the Human Hand? The Social Epistemology of Information Technology. *Journal of Documentation* 64(5): 738-59.

Whitesides, G. M., and B. Grzybowski. 2002. Self-Assembly at all Scales. *Science* 295: 5564.

Wiener, N. 1961. *Cybernetics: Or Control and Communication in the Animal and Machine*. Cambridge, MA: MIT Press.