Notes and References

1 The capriciousness of nature

1. See Drees, W.B., *Religion, Science, and Naturalism* (Cambridge University Press, 1996); and, Brooke, J.H., *Science and Religion: Some Historical Perspectives* (Cambridge University Press, 1991) for interesting, contemporary theological discussions of this point.
2. See also Hilton, H.B., *The Age of Atonement: The Influence of Evangelicalism on Social and Economic Thought 1785–1865* (Oxford University Press, 1988); and, Buckley, M., *At the Origins of Modern Atheism* (New Haven: Yale University Press, 1987) for interesting and very different discussions of this point.
3. *On Nature, the Utility of Religion, and Theism* (Longmans, Green, Reader, & Dyer, 1874).
4. Charles Darwin, for example, was appalled by the apparent squanderous cruelty and brutality of Nature. He found the idea of the natural world being the intentional creation of an all powerful and good god in accordance with a divine plan to be quite an unbelievable idea. The egg-laying habits of the Ichneumonidae (which lays them into a caterpillar host), disease (which killed his ten-year-old daughter Annie), and earthquakes were considered by Darwin to be serious evils in Nature (and contradictions against the idea of a beneficent deity). See Desmond, A. and Moore, J., *Darwin* (London: Michael Joseph, 1991) and Brooke, J.H., "Darwin" (in Brooke and Richardson, eds., *The Crisis of Evolution*, Milton Keynes: Open University Press, 1974) for further discussion and references. A similar posture of moral outrage against the blind cruelty and brutality of Nature can be found in Williams, G.C., *Plan and Purpose in Nature* (London: Orion Books, 1997) and Rolston, H., *Environmental Ethics* (Philadelphia: Temple University Press, 1988), but in these cases this moral outrage is used to justify a Christian and Kantian account of morality as being opposed to instinct.
5. For example, see Raup, D.M. and Sepkoski, J.J., "Mass Extinctions in the Marine Fossil Record", *Science*, 215, 1982, pp. 1501–3; Ward, P.D., *On Methuselah's Trail: Living Fossils and the Great Extinctions* (New York: Freeman, 1993); Myers, M., "Mass Extinction and Evolution", *Science*, 278, 1997, pp. 597–8; Nee, S. and May, R. M., "Extinction and the Loss of Evolutionary History", *Science*, 278, 1997, pp. 692–4; Hoffman, P.F. and Schrag, D.P., "Snowball Earth", *Scientific American*, 282, 2000, pp. 68–75.
6. For a contemporary scientific focus upon the apparent indifference of Nature towards individuals, see Dawkins, R., *The Blind Watchmaker* (Harlow: Longman, 1986).
7. Of course, it may well be the case that the cosmic order may well destroy human beings (or some other dominant species, from time to time) in order to restore balance – as in Sophocles' *Antigone* (New York: Dover Publications, 1993) – while being indifferent to the suffering caused by such an act of destruction.

8. Darwin, C., *The Origin of Species* (New York: Gramercy, 1995).
9. Crick, F., *What Mad Pursuit: A Personal View of Scientific Discovery* (New York: Basic Books, 1988), pp. 137–42.
10. Gould, S.J., *The Panda's Thumb: More Reflections in Natural History* (New York: W.W. Norton, 1980).
11. See Monod, J., *Chance and Necessity* (Wainhouse, trans., London: Fontana, 1974) for a very frank and forthright discussion of the consequences of this possibility.
12. Huxley, T.H., "Evolution and Ethics", p. 44 (reproduced in Paradis and Williams, eds., *Evolution and Ethics: T.H. Huxley's Evolution and Ethics, with New Essays on its Victorian and Sociobiological Context*, Princeton: Princeton University Press, 1989). Huxley's view was that "ethical nature" contradicted and struggled with "cosmic nature" in order to curb the cosmic process and compensate for the lack of the qualities that best fitted us for success within this process. He prescribed (p. 182) that human beings should be "perpetually on guard against the cosmic forces, whose ends are not his ends".
13. Spencer, H., *Social Statics*, p. 414 (New York: Appleton, 1864) asserted that it is best that the poor and unfit should die "to make room for better". Of course, as Kropotkin argued, it does not necessarily follow from Darwin's theory of evolution that competition between individuals is the only strategy for survival. His observation of many instances of cooperation between members of the same species in Siberia, one of the harshest environments on Earth, showed how there are natural selections in favour of social, altruistic, and even ethical behaviour. See Kropotkin, P.A., *Mutual Aid: A Factor of Evolution* (Freedom Press, 1987). Also see Marguilis, L. and Sagan, D., *Slanted Truths: Essays on Gaia, Symbiosis and Evolution* (New York: Copernicus Books, 1997) for some contemporary discussions by evolutionary biologists for whom cooperation is considered to be the dominant evolutionary mechanism. However, whichever interpretation of the theory of evolution we prefer, concepts of struggle and opposition are utilised to represent the natural state.
14. This is not to suggest that we are the only beings that have purposes (and, consequently, might experience events in terms of good or bad luck). It may well be possible that there are many animals in this world that have a sense of their own purpose and the value of other entities for those purposes. Even if it is a prerequisite of the definition of purpose that it is a property of a mind, requiring some degree of forethought, there is still no reason to believe that the possession of a mind is an exclusively human characteristic.
15. Rogers, K., *On the Metaphysics of Experimental Physics* (Basingstoke: Palgrave Macmillan, 2005).
16. Modern science is the realisation of an ancient dream. In Thucydides' *History of the Peloponnesian War* (Hobbes, trans., Chicago University Press, 1989), art (*techne*) is represented as the means by which human beings can struggle against natural catastrophes and overcome the harshness of Nature. The Babylonian *Enuma elish* is another example of a creation myth that depicts "Man" (the hero Marduck, in this case) in battle with Nature as primordial chaos, ultimately killing the Primordial Mother and allowing Nature to emerge as bountiful and beneficent, when dominated and controlled. See Ricoeur, P., *The Symbolism of Evil* (Boston: Beacon Press, 1967) for an

interesting discussion of this myth, as well as other discussions of the historical developments and interpretations of the idea of evil.

17. Sophocles' *Ode to Man* in *Antigone* laments the tragedy of humanity that uses art (*techne*) to conquer Nature and order human life through agriculture, animal domestication, medicine, the use of mechanical devices, and by building cities, but ultimately humanity becomes dominated by art, which perpetually innovates and drives humans forward, as it creates and destroys, making a world that is beyond human control and inhumane. Human beings end up dependent on the artificial world.
18. See Shapin, S., *The Scientific Revolution* (University of Chicago Press, 1996); and Worster, D., *Nature's Economy: A History of Ecological Ideas* (Cambridge University Press, 1977) for interesting discussions about the Enlightenment vision of a human society living in harmony within natural order.
19. Of course, as Nietzsche frequently pointed out, this gross assumption ignores the fact that throughout human history lies and falsehoods have been instrumental in the development of civilisation and power. Something does not have to be objectively true in order to bring psychological, social, and political advantages. Nor is the belief in a falsehood necessarily a disadvantage. After all, what harm results from the childhood belief in faeries, elves, or Santa Claus? Much delight and wonder arises from them.
20. For an example of a recent advocate of this view, see Wilson, E.O., *Consilience* (London: Little, Brown and Co., 1998). Also see Searle, J., *The Construction of Social Reality* (London: Penguin, 1995).
21. See Bhaskar, R., *A Realist Theory of Science* (Leeds Books, 1975), for a developed argument for the necessity of a scientific realist interpretation of experimentation. The ideas of stratification and ontological depth are fundamental to the intelligibility of experimentation, and, hence, a positivistic interpretation of science is flawed. While I agree with Bhaskar's criticisms of positivism, my criticisms of Bhaskar's realist argument can be found in *On the Metaphysics of Experimental Physics*, Chapter 2.
22. For example, see Garnder, E.J., *Principles of Genetics* (New York: John Wiley, 1975); and, Mayr, E., *Evolution and the Diversity of Life* (Cambridge, Mass.: Harvard University Press, 1976).
23. *Gaia: A New Look at Life on Earth* (Oxford University Press, 2000). See also Ayala, F.J., "The Concept of Biological Progress", in Ayala, F.J. and Dobzhansky, T. (eds), *Studies in the Philosophy of Biology* (New York: Macmillan, 1974, pp. 339–55); Valentine, J.W., *Evolutionary Paleoecology of the Marine Biosphere* (Englewood Cliffs, N.J.: Prentice Hall, 1973).
24. See Dupuy, J-P., *The Mechanization of the Mind: On the Origins of Cognitive Science* (DeBevoise, trans., Princeton University Press, 2000) for a fascinating discussion of the history of the intersection between biology, computer science, and cybernetics.
25. For example, take John Polkinghorne's representation of the stars as factories for the heavier elements necessary for the production and reproduction of life in *Beyond Science* (Cambridge University Press, 1996), p. 84. Polkinghorne actually extends the metaphor of the artificial back on itself to use it to explain the natural, and then argued that this explanation shows that God must have designed and made the Universe. A similar argument was made by the nineteenth-century evangelical Christian and geologist Hugh

Miller in *The Testimony of the Rocks* (Edinburgh: Nimmo, 1857). He argued that Nature's ability to adapt itself to human needs and wants, rendering it more pleasing to our aesthetic sense and material condition, shows that Nature is bound up with its perfection in relation to conscious purpose. This argument was used to suggest that God designed Nature.

26. Kuhn, T.S., *The Structure of Scientific Revolutions* (Chicago University Press, 1962).
27. Heidegger, M., "The Age of the World Picture" (in *The Question Concerning Technology and Other Essays*, Lovitt (trans.), Harper Torchbooks, 1977, pp. 115–54.)
28. Dawkins, R., *The Selfish Gene* (New York: Oxford University Press, 1976).
29. Weinberg, S., *The First Three Minutes* (New York: Basic Books, 1977).
30. Sagan, C., *The Demon-Haunted World: Science as a Candle in the Dark* (New York: Random House, 1996).
31. Cupitt, D., *What is a Story?* (London: SCM, 1991), p. 99; see also Negrete, A. and Lartigue, C., "Learning From Education to Communicate Science as a Good Story" (*Endeavour*, Vol. 28, No. 3, September 2004).
32. For wide-ranging discussions of the term "technoscience", see Marcus, G.E., ed., *Technoscientific Imaginaries* (University of Chicago Press, 1986); Aronowitz, S., *et al*., eds, *Technoscience and Cyberculture* (Oxford: Routledge, 1996); and Gordo-Lopez, A.J. and Parker, I., eds, *Cyberpsychology* (London: Macmillan Press, 1999).
33. Haraway, D.J., "Mice into Wormholes: A Comment on the Nature of No Nature" (in Downey, G.L. and Dumit, J. (eds), *Cyborgs & Citadels: Anthropological Interventions in Emerging Sciences and Technologies*, Santa Fe, NM: School of American Research Press, 1998, pp. 209–43), p. 210.
34. Haraway, D.J., *Primate Visions: Gender, Race, and Nature in the World of Modern Science* (New York: Routledge, 1989). See Noble, D., *Forces of Production* (Basic Books, 1984) for a discussion about how technological innovations reproduce structures of class inequalities; see also Braverman, H., *Labour and Monopoly Capitalism* (New York: Monthly Review, 1974). For insightful discussions of how technological innovations and science reproduce gender inequalities, see Schwartz Cowan, R., *More Work For Mother* (New York: Basic Books, 1983); Scott, J.W., *Gender and the Politics of History* (New York: Columbia University Press, 1988), and Merchant, C., *The Death of Nature: Women, Ecology, and the Scientific Revolution* (New York: Harper and Row, 1980).
35. Haraway, D.J., *Simians, Cyborgs, and Women: The Reinvention of Nature* (New York: Routledge, 1991).
36. Marx, K., *The Poverty of Philosophy* (Quelch, trans., New York: Prometheus, 1995), p. 1.
37. Ellul, J., *The Technological Society* (trans. Wilkinson, New York: Knopf, 1964).
38. The characterisation of rationality in modern society as being a bureaucratic evaluation of social life in terms of calculation and control was central to Max Weber's social critique in *The Protestant Ethic and the Spirit of Capitalism* (Parsons, trans., New York: Scribners, 1958).
39. Even though I have taken Ellul's idea of the technological society to be an insightful starting point in my own critique of modern society, I do not wish to discuss Ellul's Christian alternative to the technological society, except to

note that I do not share his commitment to this alternative and would rather focus my own contribution to this discussion on how we can proceed with a secular critique of the rationality of the modern world. Ellul articulated this alternative in *The Politics of God and the Politics of Man* (Grand Rapids, Mich.: Eerdmaus, 1972), and *The Ethics of Freedom* (Grand Rapids, Mich.: Eerdmaus, 1976). See also Hanks, J.M., *Jacques Ellul: A Comprehensive Bibliography* (Greenwich, Conn.: JAI Press, 1984); and, Lovekin, D., *Technique, Discourse, and Consciousness: An Introduction to the Philosophy of Jacque Ellul* (Bethlehem, Pa.: Lehigh University Press, 1991).

40. For an interesting discussion of this point, see Hughes, T.P., *Human-Built World: How To Think About Technology And Culture* (University of Chicago, 2004), pp. 110–52.
41. See Mueller, M., "Technology Out of Control" (in *Critical Review*, 1.4. 1987, pp. 24–40); and, Winner, L., *Autonomous Technology: Technics Out of Control as a Theme in Political Thought* (Mass.: MIT Press, 1977). See also Ihde, D., *Technology and the Lifeworld* (Bloomington and Indianapolis: Indiana University Press, 1990), pp. 128–44, for an interesting discussion of technical pluralism and the centrality of human choice in the development of technology. Bounded technical rationality is what Andrew Feenberg termed as "reflective technology" in *Questioning Technology* (New York: Routledge, 1999), pp. 207–10.
42. See Latour, B. and Woolgar, S., *Laboratory Life: The Social Construction of Scientific Facts* (Beverly Hills, Calif.: Sage Publications, 1979); Knorr-Cetina, K.D. and Cicourel A.V. eds, *Advances in Social Theory and Methodology: Toward and Integration of Micro- and Macro-Sociologies* (Boston, Mass.: Routledge and Kegan Paul, 1981); Hughes, T.P. (1983). *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore: Johns Hopkins University Press, 1983); Callon, M., Law, J. and Rip, A. eds, *Mapping the Dynamics of Science and Technology: Sociology of Science in the Real World* (London: Macmillan, 1986); Bijker, W.E., Hughes, T.P. and Pinch, T.J., eds, *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (Cambridge, Mass.: MIT Press, 1987); Latour, B., *Science in Action: How to Follow Scientists and Engineers Through Society* (Milton Keynes: Open University Press, 1987); Law, J. ed., *A Sociology of Monsters: Essays on Power, Technology and Domination* (Routledge, London, 1991); and, Bijker, W.E. and Law, J. (eds), *Shaping Technology – Building Society: Studies in Sociotechnical Change* (Cambridge, Mass.: MIT Press, 1992).
43. "Question Concerning Technology", in *The Question Concerning Technology and Other Essays* (Lovitt, trans., Harper Torchbooks, 1977).
44. "Letter On Humanism" (in *Basic Writings*, Farrel Krell, ed., London: Routledge, pp. 217–65), p. 255.
45. R.K. Merton made this point in his introduction to Ellul's *The Technological Society*, pp. viii–xiii. He pointed out that the technological society responds to the needs generated by technique, as if we were responding to immutable laws of development and "technology becomes more like the new god". As the historian and philosopher E.E. Fournier D'Albe succinctly and poetically wrote in 1926, in *Hephaestus or The Soul of the Machine* (London: Keegan-Paul), this god of the modern age is personified by Hephaestus, the ancient Greek god of fire and making.

46. Mumford, L., *Technics and Civilization* (Harcourt Brace & Company, 1963).
47. *Ibid.*, p. 6.
48. Mumford, L., *Pentagon of Power: The Myth of the Machine* (New York: Harcourt Brace Jovanovich, 1970). Dwight Eisenhower first referred to the military–industrial complex in his farewell presidential speech (1961) and warned that a state-supported large arms industry could have damaging political and economic consequences. Seymour Melman developed and supported this argument in detail when he argued that the military–industrial complex was having a damaging and corrupting effect on the capitalist market economy. See *Pentagon Capitalism: The Political Economy of War* (San Francisco: McGraw-Hill, 1970) and *The Permanent War Economy: American Capitalism in Decline* (New York: Simon and Schuster, 1985).
49. Sombart, W., *Modern Capitalism: A Historical-Systematic Presentation of European Economic Life from the Beginnings to the* Present (Brookwood, 1932); and *Weltanschuung, Science, and Economy* (Veritas Press, 1939).
50. Spengler, O., *Decline of the West* (Werner, trans., Oxford University Press, 1991), first published 1918–22, and *Man and Technics: A Contribution to a Philosophy of Life* (California: University Press of the Pacific, 2002), first published in 1931.
51. Mitcham, C., *Thinking Through Technology: The Path Between Engineering and Philosophy* (University of Chicago Press, 1994).
52. Paul Tillich pre-empted and inspired many of Heidegger and Ellul's ideas, but his influence on the humanist tradition has been overlooked. For example, see his essay "The Logos and Mythos of Technology" (first published in 1927) and "The Technical City as Symbol" (first published in 1928) in Thomas, J.M. (ed.), *The Spiritual Situation in Our Technical Society* (Macon, Georgia: Mercer University Press, 1988).
53. Borgmann, A., *Technology and the Character of Contemporary Life* (Chicago: University of Chicago Press, 1984).
54. Habermas, J., *Toward a Rational Society: Student Protest, Science, and Politics* (Shapiro, trans., Boston: Beacon Press, 1970); *Legitimation Crisis* (McCarthy, trans., Boston: Beacon Press, 1975).

2 The metaphysics of modern science

1. For example, see Greenberg, D., *The Politics of Pure Science* (New York: New American Library, 1967); Bloor, D., *Knowledge and Social Imagery* (Oxford: Routledge, 1976); Latour, B. and Woolgar, S., *Laboratory Life* (Beverly Hills, Calif.: Sage Publications, 1979); Foucault, M., *Knowledge/Power: Selected Interviews and Other Writings, 1972–1977* (Gordon, trans., ed., New York: Pantheon Books, 1980); Knorr-Cetina, K., *The Manufacture of Knowledge* (Pergamon Press, 1981); Easlea, B., *Fathering the Unthinkable: Masculinity, Scientists, and the Nuclear Arms Race* (London: Pluto Press, 1983); Collins, H.M., *Changing Order: Replication and Induction in Scientific Practice* (London: Sage Publications, 1985); Harding, J., ed., *Perspectives on Gender and Science* (London: Falmer Press, 1986); Ince, M., *The Politics of British Science* (Brighton: Wheatsheaf, 1986); Billig, D., *Arguing and Thinking* (Cambridge University Press, 1987); Galison, P., *How Experiments End* (University of

Chicago Press, 1987); Latour, B., *Science in Action* (Milton Keynes: Open University Press, 1987); Suchman, L., *Plans and Situated Actions* (Cambridge University Press, 1987); Gooding, D., Pinch, T., and Schaffer, S., eds, *The Uses of Experiment: Studies in the Natural Sciences* (Cambridge University Press, 1989); Danziger, K., *Constructing the Subject* (Cambridge University Press, 1990); Gooding, D., *Experiment and the Making of Meaning* (Dordrecht: Kluwer Academic Publishers, 1990); Pickering, A., ed., *Science as Practice and Culture* (Chicago University Press, 1992); Galison, P. and Stump, D., eds, *The Disunity of Science: Boundaries, Contexts and Power* (Stanford University Press, 1996); and, Galison, P., *Image and Logic: A Material Culture of Microphysics* (Chicago University Press, 1997).

2. For example, see White, L., *Medieval Technology and Social Change* (Oxford University Press, 1962); Merton, P.K., *Science, Technology, and Society in Seventeenth Century England* (Cambridge University Press, 1970); Mathias, P., ed., *Science and Society 1600–1900* (Cambridge University Press, 1972); Bennett, J.A., "The Mechanics' Philosophy and the Mechanical Philosophy" (in *History of Science*, 1986, pp. 1–28); Yearly, S., *Science, Technology, and Social Change* (London: Unwin Hyman, 1988); Kaufman, T.D., "Astronomy, Technology, Humanism, and Art at the Entry of Rudolf II into Vienna, 1577" (in *The Mastery of Nature: Aspects of Art, Science, and Humanism in the Renaissance*, Princeton University Press, 1993, pp. 136–50); and Long, P.O., "Power, Patronage, and the Authorship of *Ars*: From Mechanical Know-how to Mechanical Knowledge in the Last Scribal Age" (in *ISIS*, 88, 1997, pp. 1–41).
3. *MEP*, Chapter 3.
4. Aristotle, NE 6.4; Metaphysics 1.1; Rhetoric 1.2 (*The Complete Works*, 2 vols, Barnes, ed., trans., Princeton University Press, 1984). For both Plato and Aristotle, *techne* referred to the general, abstract, and communicable first principles of making and inscription in the activities of craftsmanship and art. It is how *techne* was related to *episteme* (commonly translated as "science" or "knowledge of eternal and necessary principles") that differed between Plato and Aristotle. Both Plato and Aristotle considered mathematics and mechanics as *technai* along with agriculture, building, medicine, pottery, painting, sculpture, and rhetoric. However, in Plato's works, *techne* and *episteme* were used interchangeably to characterise geometrical reasoning in particular. See *Philebus* (55c–56d), *Gorgias* (450b–c), and *Ion* (532) (*The Complete Works*, Cooper, ed., Cambridge, Mass.: Hackett Publishing, 1997), for example. The mathematical activities of numbering, measuring, or weighing were taken to be the most truly *technai* because they were taken to involve the greatest precision and were more closely associated with the activities of making that operate upon the material world. These reasoned activities operated by guiding acts of making through the use of mathematics, and the *techne* of such activities, provided a formal knowledge and rules by which material practices were performed, governed, and understood. However, in *Philebus* (56d), *epistemoi* such as arithmetic and geometry were distinguished from *technai* such as carpentry because the former deals with abstract numbers and proportions whereas the latter uses numbers and proportions to deal with materials. In *The Statesman* (258e), *episteme* was used to denote pure theory or any knowledge that did not

relate to the material world in a practical manner. *Episteme* was reserved for knowledge learnt for its own sake, whereas *techne* was always directed towards the production of something else.

5. *NE* 6.4.1140a11.
6. See *Metaphysics* 7.8.1033b20–1034a7 and 7.9.1034a10–11. For Aristotle, no two lumps of clay were alike and a potter cannot make the same pot twice. *Hyle* was the particularity of any particular lump of clay and did not refer to the clay-like properties of the substance called "clay". It referred to the way that each and every pot, as well as the experience of making them, is different; even though all pots are all made out of the same substance in accordance with the same *techne*.
7. *Physics* 2.2.194a23.
8. *NE* 2.9.1109b23.
9. *NE* 2.1.1103a35 and *Metaphysics* 1.1.980b25ff.
10. *Metaphysics* 7.9.1034a10–11.
11. *Physics* Bk.2 and *Metaphysics* Book IV. He used *techne* to elucidate his conception of *phusis* as teleological (requiring *tuche*, meaning luck or chance, as a third explanatory concept).
12. See Waterlow, S., *Nature, Change, and Agency in Aristotle's Physics* (Oxford: Clarendon Press, 1982); and, Daston, L. and Park, K., *Wonders and the Order of Nature* (New York: Zone Books, 1998) for further discussion of this point.
13. *Politics* 11252b1–5. Plato was critical of the relation between mimicry (*mimesis*) and art (*Rep*. Bk. X, 596b–598c) due to the fact that the artist is a creator of an illusion (601c9) who leads the viewer away from reality. Plato described the artist as a stage magician who uses tricks (*mechanai*) in order for us to accept his imitation of Nature as being the real thing. Art is mistrusted. Art is a counterfeit.
14. The medieval Aristotelian categories of the academic disciplines included all productive pursuits, including mechanics, under the general rubric of "arts". See Weisheipl, J.A., "The Nature, Scope, and Classification of the Sciences" (in Lindberg, D.C., ed., *Science in the Middle Ages*, Chicago University Press, 1978, pp. 461–82) for further discussion and references.
15. See Pérez-Ramos, A., *Francis Bacon's Idea of Science and the Maker's Knowledge Tradition* (Oxford: Clarendon Press, 1988); and, Rossi, P., *Philosophy, Technology, and the Arts in the Early Modern Era* (Attonasio, trans., New York: Harper and Row, 1970), pp. 137–45.
16. *The New Organon* (Jardine and Silverthorne, eds, Cambridge University Press, 2000), pp. 20–1.
17. *Ibid*., pp. 69–70.
18. *Ibid*., p. 100.
19. *MEP*, Chapter 3.
20. See also Smith, P.H., *The Body of the Artisan: Art and Experience in the Scientific Revolution* (University of Chicago Press, 2004) for an interesting discussion of this point.
21. *New Organon*, p. 33. Note that the word "results" is a translation of the Latin *opera*, also meaning "effects" or "work". It is a derivative from *operatio*, translated as "operation" or "practice".
22. Mechanics was established as a mathematical science in sixteenth-century Italy through the influence of the University at Padua. Since the fourteenth

century, Padua had been a centre for mathematical subjects (including astronomy, astrology, geometry, optics, and geography) and was the first Italian university in the sixteenth century to offer lectures in mechanics from the chair of mathematics. Mechanics was first introduced at Padua in the 1560s in the form of lectures on Aristotelian mechanics. See *MEP*, Chapter 3 for discussion and references.

23. Moletti's arguments can be found in *In librium mechanicorum Aristotelis expositio tumultaria et ex tempore*. Milan, Biblioteca Ambrosiana MS. S 100.
24. See *MEP*, Chapter 3. See also McMullin, E., ed., *Galileo: Man of Science* (New York: Basic Books, 1967), pp. 256–92.
25. *On Motion and Mechanics* (trans., Drabkin and Drake, Madison: University of Wisconsin Press, 1960), p. 421.
26. This is evident from Galileo's use of a pendulum to demonstrate his theory of motion (*On Motion and Mechanics*, pp. 152–3); an astronomical sphere to demonstrate his theory about the Sun's rotation (pp. 348–9); and steelyards and balances to demonstrate his theory of free-fall (pp. 213–4). Having chosen the balance as fundamental and used it to derive the laws for an inclined plane, the lever, the windlass, the capstan, the pulley, and the screw, Galileo constructed a "dynamic equilibrium" method as the basis of his physics. He used this method in his treatment of hydrostatic phenomena in *Discourse on Floating Bodies* (1612) and in his *Dialogue on the Two Chief World Systems* (1632). He used this method to describe motion as separated into two independent axes, horizontal and vertical motion, to describe the fall of a body from a moving point as that of a parabola. He then rhetorically used this to argue that the Earth could revolve around the Sun (without the breath being snatched from our mouths, nor birds being flung from out of the sky). In *Dialogues Concerning Two New Sciences* (1638), he concentrated on explaining natural motion using the inclined plane. This involved using the pendulum and the balance as exemplars for his description of all natural motion and his thought experiments.
27. Bridgman, P.W., *The Logic of Modern Physics* (New York: Macmillan, 1928).
28. This is most evident in *Dialogues Concerning Two New Sciences* (Crew and de Salvio, trans., Evanston: Northwestern University Press, 1914) within which Galileo proposed the derivation of "most other mechanical devices" in terms of "the Law of the Lever" (pp. 110–2), defined his notion of force (*forza*) in terms of the lever as "mechanical advantage" (p. 124), and proposed the balance as the basic explanatory trope. Any external force could itself be simply described by mathematically projecting the lever as a half-balance.
29. See Machammer, P., "Galileo's Machines, His Mathematics, and His Experiments" (in *The Cambridge Companion to Galileo*, Machammer, ed., Cambridge University Press, 1998), for further discussion of how the balance, as a metaphor and a model, became central to every physical explanation and law.
30. See Osler, M., *Divine Will and the Mechanical Philosophy: Gassendi and Descartes on Contingency and Necessity in the Created World* (Cambridge University Press, 1994), Chapter 5; Shea, W.R., *The Magic of Numbers and Motion: René Descartes' Scientific Career* (Mass.: Science History Publications, 1991); and Heidegger, M., "Modern Science, Metaphysics, and Mathematics" (in *Basic Writings*, Farrel Krell, ed., London: Routledge, 1999),

pp. 267–306, and "On the Essence and Concept of *Phusis* in Aristotle's *Physics* Book I" (in McNeill, ed., *Martin Heidegger: Pathmarks*, Sheenan, trans., Cambridge University Press, 1998), pp. 183–230, for further discussions of this point.

31. Descartes, R., *Principles of Philosophy* (Miller and Miller (eds, trans.), Dordrecht: Reidel, 1983), p. 285. See the revised Adam and Tannery edition of *Oeuvres de Descartes* (Paris: Vrin/C.R.N.S., 1966–76, II, pp. 541–44) for a letter that Descartes wrote to Florimond de Beaune (dated April 1639) in which he described the new physics as "merely mechanics". See *MEP*, Chapter 3, for discussion.
32. See *Principles*, pp. xxvi–xxvii and p. 85. See Garber, D., "Science and Certainty in Descartes" (in *Descartes: Critical and Interpretive Essays*, Hooker (ed.), Baltimore: John Hopkins University Press, 1978, pp. 114–151) and Clarke, D.M., *Descartes' Philosophy of Science* (Pennsylvania State University Press, 1982) for further discussion of this point.
33. For a detailed discussion of Descartes' concept of living beings as mechanistic automata, see Des Chene, D., *Spirits and Clocks: Machine and Organism in Descartes* (Ithaca: Cornel University Press, 2001).
34. *Discourse on Method and The Meditations* (Sutcliffe, trans., Penguin Books, 1968), p. 78.
35. *Ibid*., p. 91.
36. See Schaffer, S., "Glass works: Newton's prisms and the uses of experiment" (in Gooding *et al*. eds, *The Uses of Experiment*, Cambridge University Press, 1989), pp. 67–104, for a detailed discussion and references.
37. See *MEP*, Chapter 3, for discussion and references.
38. See Newton's "Preface to the 1st Edition" of *Principia*, pp. xvii–xviii and pp. 398–9 (*The Mathematical Principles of Natural Philosophy and The System of the World*, 2 volumes, Cajori, ed., trans., University of California Press, 1962).
39. "The Origin of Forms and Qualities According to the Corpuscular Philosophy" (1672) (vol. 3 of *The Works of the Honourable Robert Boyle*, Birch, ed., 6 volumes, Hildesheim: Georg Olms, 1965), p. 13; Shapin, S. and Shaffer, S., *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton University Press, 1985); and *MEP* Chapters 3 and 4.
40. Preface, *Micrographia* (London, 1665). See R.S. Westfall, "Robert Hooke, Mechanical Technology, and Scientific Investigation" (in Burke, ed., *The Uses of Science in the Age of Newton*, Berkeley, Calif.: Berkeley University Press, 1983), pp. 85–110; and *MEP*, Chapter 4.
41. Carlino, A., *Books of the Body: Anatomical Ritual and Renaissance Learning* (Anne and John Tedeschi, trans., University of Chicago Press, 1999); Persaud, T.V.N, *A History of Anatomy: The Post Vesalian Era* (Spring Field, Il.: Charles Thomas, 1997); Sawday, J., *The Body Emblazoned: Dissection and the Human Body in Renaissance Culture* (Oxford: Routledge, 1996); and Whitteridge, G., *William Harvey and the Circulation of the Blood* (New York: American Elsevier, 1971).
42. For detailed discussions, see Allen, G.E., *Life Science in the Twentieth Century* (New York: Wiley, 1975); Sayre, A., *Rosalind Franklin and DNA* (New York: Norton, 1975); Gould, S.J., *Ontogeny and Phylogeny* (Cambridge, Mass.: Harvard University Press, 1977); Barnes, B. and Shapin, S., *Natural Order: Historical Studies of Scientific Culture* (Beverly Hills, Calif.: Sage, 1979);

Mayr, E. and Provine, W., eds, *The Evolutionary Synthesis* (Cambridge, Mass.: Harvard University Press, 1980); Farber, P., "The Transformation of Natural History in the Nineteenth Century", *Journal of the History of Biology*, 1982, 15, pp. 145–52; Sapp. J., "The Struggle for Authority in the Field of Heredity, 1900–1932: New Perspectives on the Rise of Genetics", *Journal of the History of Biology*, 1983, 16, pp. 311–342; Kevles, D.J., *In the Name of Eugenics: Genetics and the Uses of Human Heredity* (New York: Knopf, 1985); Pauly, P.J., *Controlling Life: Jacques Loeb and the Engineering Ideal in Biology* (New York: Oxford University Press, 1987); Haraway, D., *Primate Visions: Gender, Race, and Nature in the World of Modern Science* (New York: Routledge, 1989); Foucault, M., *The Order of Things: An Archaeology of the Human Sciences* (New York: Vintage Books, 1994); Lee, K., *Philosophy and Revolutions in Genetics* (Palgrave Macmillan, 2002); and, Trusted, J., *Beliefs and Biology* (Basingstoke: Palgrave Macmillan, 2003).

43. For an interesting history of the emergence of ecological science as an empirical science, see Worster, D., *Nature's Economy: The Roots of Ecology* (Garden City, New York: Anchor Books, 1979).
44. Dupuy, *The Mechanization of the Mind: On the Origins of Cognitive Science* (DeBevoise, trans., Princeton University Press, 2000).
45. See *MEP*, Chapters 4 and 5, for a detailed discussion of this.
46. Hacking, I., *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science* (Cambridge University Press, 1983).
47. Gooding, D., *Experiment and the Making of Meaning* (Dordrecht: Kluwer Academic Publishers, 1990).
48. Cartwright, N., *The Dappled World: A Study of the Boundaries of Science* (Cambridge University Press, 1999).
49. Bhaskar, R., *A Realist Theory of Science* (Leeds Books, 1975).
50. *Ibid.*, pp. 87–90.
51. *Ibid.*, p. 112.
52. Kroes, P. and Meijers, A., eds, *The Empirical Turn in the Philosophy of Technology: Research in Philosophy and Technology, Volume 20* (Oxford: Elsevier Science, 2000). See also Rothbart, D., "The Dual Nature of Chemical Substance", *Techne*, 6:2, 2002, pp. 28–33.

3 The technological society

1. Friedrich Dessauer (1881–1963) was a proponent of the view that the technological imperative to transform the world for the better was a moral imperative and brought human beings into contact with things-in-themselves. The creative process of invention creates existence out of essence and the result is a working, practical solution to a problem. The autonomous, world-transforming consequences of modern technology demonstrate its transcendent moral value and, for Dessauer, technology had become a new way for human beings to exist in the world that fitted into the Kantian understanding of a categorical imperative. Dessauer was a devout Catholic and a German philosopher, who wrote several books on theology, defended technology in the strongest possible terms, sought to open up dialogue with existentialists, social theorists, and theologians, and opposed

Hitler. For this last act he was forced to flee Germany. For discussion of Dessauer, see Mitcham, *Thinking Through Technology*, pp. 29–33; and Klaus Tuchel, "Friedrich Dessauer as Philosopher of Technology: Notes on His Dialogue with Jaspers and Heidegger" (in *Research in Philosophy and Technology*, vol. 5, pp. 269–80, Durbin (ed.), Greenwich, Conn.: JAI Press, 1982).

2. *Technological Society*, pp. 38–45.
3. *Ibid.*, p. 86.
4. *Ibid.*, p. 5 and 21. For Ellul's discussions about the relationships between Nature, magic, and technique in primitive societies, see pp. 24–7, 36–7, and 64–9. See *MEP*, Chapter 1, for a discussion of the parallels between Ellul and Heidegger, as well as my criticisms of Ellul's analysis of the distinction between science and technology.
5. *Ibid.*, p. 24.
6. *Ibid.*, pp. 5 and 53. Ellul cites Mumford's *Technics and Civilization* as support for this claim, but as I shall explain in the next section, Mumford's view on the relationship between technology and capitalism was more complicated and critical than this.
7. *Ibid.*, pp. 104–5.
8. *Ibid.*, p. 184.
9. *Ibid.*, p. 197.
10. *Ibid.*, p. 144.
11. *Ibid.*, pp. 200–201.
12. *Ibid.*, p. 198 and pp. 236–7.
13. *Ibid.*, p. 81.
14. Ellul, J., *The Technological Bluff* (Bomiley, trans., Grand Rapids, Mich.: Eerdmans, 1990).
15. See Landes, D., *Bankers & Pashas: International Finance and Economic Imperialism in Egypt* (Cambridge, Mass.: Harvard University Press, 1959) for an interesting account of the emergence of capitalism.
16. *Technics and Civilisation*.
17. See Lovins, A.B., *Soft Energy Paths: Toward a Durable Peace* (New York: Harper & Row, 1979), for an interesting discussion about how alternative technologies were suppressed by the oil and car industries. Over 26 years later, we see that not much has changed.
18. *T&C*, pp. 167–8. Benjamin Franklin proposed a method to utilise unburnt carbon in coal smoke by recycling and burning it a second time in the furnace. This method was never used. Steam power is highly inefficient. About 90 per cent of the heat produced escapes in the steam and smoke. The steam engine was also extremely noisy. James Watt's efforts to improve the efficiency of the steam engine and reduce its noise were dismissed as being too expensive to implement.
19. *Ibid.*, p. 181.
20. *Ibid.*, p. 185.
21. *Ibid.*, p. 285.
22. *Ibid.*, p. 255.
23. See Stiegler, B., *Technics and Time, 1: The Fault of Epimetheus* (Beardsworth and Collins, trans., Stanford University Press, 1998) for an interesting discussion of how this made the temporality of life meaningless by construing all labour and technical action in terms of its value, measured in terms of time and function, for the future.

24. For Marx, the social mode of production is the dominant historical factor and, hence, the hand-mill was bound up with selfdom in a feudal system, and the steam mill with the wage-labour of industrial capitalism. See *The Poverty of Philosophy*, Chapter II. For discussions of the technological determinism inherent to Marxist ideology, see D. Mackenzie, "Marx and the Machine", *Technology and Culture*, 25, July 1984, pp. 473–502; and Winner, *Autonomous Technology*, pp. 65–75.
25. *Capital* I (Engels, ed., More and Aveling, trans., New York: International Publishers, 1967), p. 441.
26. *T&C* p. 263.
27. *Ibid.*, p. 258.
28. *Ibid.*, pp. 264–6.
29. *Ibid.*, p. 213.
30. *Ibid.*, p. 211.
31. In the *Dialectics of Nature*, Engels extended Marx's theory beyond its limits as a method for understanding history and social reality, based upon scientific realism, and developed the dialectical method from the results of contemporary natural science. Leon Trotsky stated that human beings should use science and technology to rearrange mountains and rivers, to improve on Nature and transform the world according to human choice. See *Literature and Revolution* (University of Michigan, 1960), pp. 251–3.
32. As Langdon Winner pointed out in *Democracy in a Technological Society* (Dordrecht: Kluwer Academic Publishers, 1992), p. 3, "The fact that various communist and socialist alternatives have now fallen into disfavour has not eliminated the fundamental problems that gave rise to them."
33. *Capital* I, p. 578.
34. *One-Dimensional Man* (Boston: Beacon Press, 1991) was first published in 1964. It presupposed the ideals and vision of a free and rational society articulated in *Reason and Revolution* (first published in 1941) and *Eros and Civilization* (first published in 1955). In response to his critics, Marcuse modified and developed his description and analysis of one-dimensional society in his later works *An Essay on Liberation* (1969) and *Counterrevolution and Revolt* (1972), but his basic position against social forms of domination and conformity remained the same until his death in 1979.
35. *One-Dimensional Man*, pp. 226–7.
36. *Ibid.*, p. 17.
37. Marcuse was critical of the "one-dimensional" trajectory of both industrial capitalist and communist countries. In his book *Soviet Marxism* (New York: Columbia University, 1958), Marcuse was highly critical of the USSR, but he rejected the Western countries' Cold War propaganda that claimed the moral superiority of capitalism over communism.
38. Marcuse considered the dialectical method as demonstrated in the dialogues of Plato to have been one of the most influential sources for Renaissance metaphysics.
39. *ODM*, p. 153.
40. *Ibid.*, pp. 156–7.
41. *Ibid.*, p. 158.
42. *Ibid.*
43. Marcuse accepted Husserl's interpretation of Galileo's physics having emerged from and referred back to a pre-scientific world of practice and

practical arts. In my view, this is correct but fails to address the question of how it was possible for Galileo to epistemologically connect the practical arts with natural philosophy. Husserl failed to show how Galileo was able to connect geometry with practical activity in such a way as to correlate ideational truth with empirical reality through mechanical devices.

44. In the sense of being defined in terms of (1) the validation of cognitive thought by the facts of experience; (2) the orientation of philosophical thought to the physical sciences as the model of scientific thought; (3) the belief that progress depends upon this orientation; (4) the rejection of all metaphysics; and (5) the object world is understood in terms of its instrumentality. See *ODM*, p. 172.
45. *Ibid.*, p. 136, f.n. 4.
46. Marcuse, H., *An Essay on Liberation* (Boston: Beacon Press, 1972), p. 19.
47. *T&C* p. 269.
48. See Horkheimer, M. and Adorno, T., "The Culture Industry: Enlightenment as Mass Deception", in *Dialectic of Enlightenment* (Calif.: Stanford University Press, 2002), pp. 94–136; and also Ellul, J., *Propaganda: The Formation of Men's Attitudes* (New York: Vintage Books, 1964), for fascinating analyses and discussions of conformity and mass democracy.

4 The confrontation with nature

1. In *Leviathan* (London: Penguin Classics, 1982), Hobbes asserted that we could only have knowledge of those things that we made ourselves, and, therefore, we could only have certain knowledge about society and its material products. In the materialism of Hobbes, the origin of all knowledge, including mathematical knowledge, is in the world accessible to the senses. On such an account, human desires and actions are the consequences of matter and motion governed by natural laws. Freedom and power are identical. The representations of the objects of the world that we induce or infer on the basis of our senses are tested on the basis of their practical utility in achieving the success of our intentions. The instrumentality of our representations for achieving our purposes is taken to be proof of their connection with reality. Such representations are falsified if and when their use is taken to be the cause of our failure to achieve our ends. In this way, according to Hobbes, all the qualities of a thing are knowable through perception and the "thing in itself" is the sum total of all these perceptions plus the intuition that the thing must exist without us. In other words, whilst Hobbes intuitively acknowledged the independent existence of the world from perception (given that perception is nothing more than the consequences of matter and motion governed by natural laws), the properties of things are exactly those properties that can be represented and are practically useful to human beings. Thus human history becomes identical with natural history in so far as both are descriptions of the motion of matter in accordance with immutable natural laws. For further discussion, see Mintz, S.I., *The Hunting of the Leviathan: Seventeenth Century Reactions to the Materialism and Moral Philosophy of Thomas Hobbes* (Cambridge University Press, 1969).

2. Horkheimer and Adorno, *Dialectic of Enlightenment*, p. 17.
3. *Ibid*., p. xiv. See also Horkheimer, M., *Critique of Instrumental Reason: Lectures and Essays since the End of World War II* (O'Connell *et al*., trans., New York: Continuum, 1974); and Adorno, T., *The Stars Down to Earth, and Other Essays on the Irrational in Culture* (Crook, ed., London: Routledge, 1994).
4. *Techne* was the possession of the most helpless, unshod, unarmed, unclad, but highest animal who could, through *techne*, turn this weakness around, take advantage of *phusis*, and even complete that which *phusis* left incomplete (*Physics* 2.8; *Politics* 1337a1–2). For Aristotle, *techne* was rooted in and a completion of *phusis* to the extent that even human nature was completed by *techne* through medicine, crafts, and politics (*Physics* 193b10 and 2.1.193a12–17; *Politics* 1.2.1253a2).
5. *On the Natural Faculties* (Brock, A.J., trans., London: Heinemann, 1947).
6. *Natural History* (Healy, trans., London: Penguin Classics, 1991), Bk. 21, XXII.
7. See *MEP*, Chapter 3, for discussion and references. See also Laird, W.R., "The Scope of Renaissance Mechanics", *Osiris*, 2nd series, 2 (1986), pp. 43–68; and Hackett, J., ed., *Roger Bacon and the Sciences* (Leiden: Brill, 1997) for further discussion.
8. Newman, W.R., *Promethean Ambitions* (University of Chicago Press, 2004).
9. *Ibid*., p. 33. Of course, some readers will point out that alchemy could not fulfil its promises and it was a pseudo-science, whereas genetics is a proper science. While I acknowledge this point, it seems to me, on one side, that it is somewhat Whiggish because the early alchemists did not know what the limits of their art were and which of their claims were fantastic, thus the purpose of their efforts were to discover these things by trying to realise their claims, and, on the other side, is also somewhat presumptive because it assumes that genetic engineering will be able to realise the equally fantastic claims made about its potential. It may well be the case that genetic engineering will not fulfil its promises and, hence, could more similar to alchemy than some people would like to think.
10. The Jewish golem is distinct from the Arabic homunculus created by alchemy. The golem is created from the magical/divine power of words, whereas the homunculus is created from an alchemical process involving sperm being mixed with other substances and being inserted into an artificial matrix. The idea of the golem was to provide a parable of human folly and limitation (in some sense the golem is always a failure), whereas the homunculus was used to describe an ideal conception of human being in terms of intellect and moral character (as well as often being capable of magical powers). The golem is created by the magic of words, but lacks speech and intelligence, whereas the homunculus lacks the imperfections of natural being and thereby struggles to live in the imperfect natural world. For further discussion, see Pines, S., "The Origin of the Tale of Salaman and Absal: A Possible Indian Influence" (in Pines, *Studies in the History of Arabic Philosophy*, Jerusalem: Magnes Press, 1996, pp. 343–53); Idel, M., *Jewish Magical and Mystical Traditions on the Artificial Anthropoid* (Albany: State University of New York Press, 1990); and Newman, *Promethean Ambitions*, Chapter 4.
11. *PA*, pp. 301–2.
12. For contemporary examples of this utopian vision of the biotechnological society, see Naam, R., *More Than Human: Embracing the Promise of Biological*

Enhancement (New York: Broadway, 2005); and Easterbrook, G., *A Moment on the Earth: The Coming Age of Environmental Optimism* (London: Penguin, 1996). Current developments in biotechnology have recently led lesbian proponents of gynogenesis to advocate the use of biotechnology to artificially produce a completely female humanity on the premise that such a society would be a considerable advance over the natural state of affairs. For an example, see Sourbut, E., "Gynogenesis: A Lesbian Appropriation of Reproductive Technologies" (in Lykke, N. and Braidotti, R., eds, *Between Monkeys, Goddesses, and Cyborgs: Feminist Confrontations with Science, Medicine, and Cyberspace*, London: Zed Books, 1996, pp. 227–41).

13. *PA*, Chapter 2.
14. *Meteorology* (IV 3 381b3–9). See *PA*, pp. 64–6, for discussion.
15. *PA*, pp. 145–63, for discussion. See also Dalton, L. and Park, K., *Wonders and the Order of Nature* (New York: Zone Books, 1998).
16. Both Boyle and Newton considered alchemy to be a legitimate way of investigating natural processes and laws. For further discussion of the alchemical interest and experiments of Boyle and Newton, see Principe, L., *The Aspiring Adept: Robert Boyle and his Alchemical Quest* (Princeton University Press, 2000) and Dobbs, B.J.T., *The Janus Face of Genius: The Role of Alchemy in Newton's Thought* (Cambridge University Press, 2002). John Locke wrote down a method to spontaneously generate toads or serpents from a rotting goose or duck carcase (MS Locke C44, Bodleian Library, Oxford University). This method was taken from Robert Boyle's notes on palingenesis. See Boyle's essays "Essay on the Holy Scriptures" and "Some Physio-Theological Considerations About the Possibility of the Resurrection" in *The Works of Robert Boyle* (Hunter and Davis, eds, London: Pickering & Chatto, 2000). For interesting discussions of the historical connections between science and magic, see also Thorndike, L., *History of Magic and Experimental Science* (New York: Columbia University Press, 1934); Yates, F., *Giordano Bruno and the Hermetic Tradition* (Chicago University Press, 1964); Rossi, B., *Francis Bacon: From Magic to Science* (Rabinovich, S., trans., London: Routledge & Keegan Paul, 1968); and Copenhauer, B., "Natural Magic, Hermetism, and Occultism in Early Modern Science" (in Lindberg, D.C. and Westman, R.S., *Reappraisals of the Scientific Revolution*, Cambridge University Press, 1990, pp. 261–301).
17. *PA*, pp. 256–71.
18. Moran, B., *Distilling Knowledge: Alchemy, Chemistry, and the Scientific Revolution* (Harvard University Press, 2005).
19. Newman did acknowledge that mechanics was an important influence on Robert Boyle, in reference to a paper by Margaret Cook ("Divine Artifice and Natural Mechanism: Robert Boyle's Mechanical Philosophy of Nature" in *Osiris*, 2nd series, 16, 2001, pp. 133–50), but he neglected to relate that influence to practical activity and the growing dominance of maker's knowledge as a knowledge of natural laws.
20. *The New Atlantis and The Great Insaturation* (Wheeling, Il.: Harlan Davidson, 1989). For further discussion, see Price, B., ed., *Francis Bacon's The New Atlantis: New Interdisciplinary Essays* (Manchester University Press, 2003).
21. According to Augustine's conception of "original sin" and "free will", the cruelty and suffering inflicted upon human beings by Nature was taken

to be a consequence of Adam's disobedience and fall from grace, but on such an interpretation there was not any notion of progress on Earth. The sublime Parousia of the grace of Eden can only be regained through redemption and it cannot be achieved through human labour and struggle. See Hefner, P., *The Human Factor: Evolution, Culture, and Religion* (Minneapolis: Fortress Press, 1993); and Brooke, J.H. and Cantor, G., *Reconstructing Nature: The Engagement of Science and Religion* (New York: Oxford University Press, 1998), for contemporary Christian theological discussions of this problem. See Orange, D., "Oxygen and the One God" (*History Today*, 24, 1974, pp. 773–81) for a discussion of how Joseph Priestly subsumed his notion of Providence under concepts of scientific and technological progress towards a better world. Also see Horkheimer and Adorno, *Dialectic of Enlightenment*, for an interesting discussion of the use of science to achieve a god-like mastery and gaze over Nature.

22. In his essay "Nature", first published in 1874, Mill argued that everything that is artificial is also natural.
23. "The Question Concerning Technology" (in *The Question Concerning Technology and Other Essays*, Lovitt, trans., Harper Torchbooks, 1977, pp. 3–35).
24. As well as *QCT*, see "Modern Science, Metaphysics, and Mathematics" (in *Basic Writings*, Farrel Krell, ed., London: Routledge, pp. 267–306). See also, *MEP*, Chapters 3 and 4, for critical discussion of Heidegger's philosophy of physics.
25. See Aristotle (N.E. Bk. 6) for his distinctions between the intellectual virtues of *episteme, techne, sophia, nous*, and *phronesis*. The criticism of the dominance of the intellectual virtue of *techne* in modern society was central to the critical analyses of modern society presented by Arendt, H., *The Human Condition* (Chicago University Press, 1958); Habermas, J., *Theory and Practice* (Viertel, trans., Boston: Beacon, 1973); and Dunne, J., *Back to the Rough Ground: "Phronesis" and "Techne" in Modern Philosophy and in Aristotle* (Indiana: University of Notre Dame Press, 1993).
26. *QCT*, pp. 6–13.
27. For further discussion of this point, see Rothenberg, D., *Hand's End: Technology and the Limits of Nature* (Los Angeles: University of California Press, 1993).
28. *MEP*, Chapters 4 and 5.
29. "Letter on Humanism" (in *Basic Writings*, Farrel Krell, ed., London: Routledge, 1999, pp. 217–65), p. 259, footnote.
30. Geyer, F. and van der Zouwen, J., eds, *Sociocybernetics: Complexity, Autopoiesis, and Observation of Social Systems* (Westport, Conn.: Greenwood Press, 2001).
31. For example, see Levidow, L. and Young, B., eds, *Science, Technology, and the Labour Process: Marxist Studies* (London: CSE, 1981).
32. Critical realism presumes mechanical realism and the rationality of the societal gamble, given that it assumes that scientific knowledge is good and that human emancipation depends on a scientific and dialectical relation between transitive human activity and intransitive natural structures and laws. This philosophical movement grew out of the writings of Roy Bhaskar and owes a considerable debt to Marxism. Of particular importance are Bhaskar's books *Scientific Realism and Human Emancipation* (London: Verso

1986); *The Possibility of Naturalism* (New York: Harvester Wheatsheaf, 1989); and *Dialectic: The Pulse of Freedom* (London: Verso, 1993).
33. Kolakowski, L., *Marxism and Beyond: On Historical Understanding and Individual Responsibility* (Peel, trans., London: Pall Mall Press, 1968), p. 66.
34. Lukács, G., *History and Class Consciousness* (Livingston, trans., London: Merlin Press, 1967).
35. *Ibid.*, p. 231.
36. *Ibid.*, pp. 157–8.
37. "What is Orthodox Marxism?" *ibid.*, pp. 1–25.
38. See *Dialectics of Nature* (Chapter IX).
39. *H&CC*, p. 83.
40. Passmore, J., *The Perfectibility of Man* (London: Duckworth, 1970), p. 240.
41. For example, see Plumwood, V., *Feminism and the Mastery of Nature* (London: Routledge, 1993) and Lee, K., *Philosophy and Revolutions in Genetics* (Basingstoke: Palgrave Macmillan, 2003).
42. For critical discussions of whether biotechnology is actually based on good science, see Lee, K., *Philosophy and Revolutions in Genetics* (Palgrave Macmillan, 2003); and Ho, Mae-Wan, *Genetic Engineering: Dream or Nightmare? The Brave New World of Bad Science and Big Business* (Bath: Gateway, 1998).
43. Marshall McLucan, in *Understanding Media* (New York: McGraw Hill, 1964), p. 46, said technology reduces us to being "the sex organs of the machine world". Perhaps the development of biotechnology will make us redundant in that capacity too.
44. Mannheim, K., *Ideology and Utopia* (Wirth and Shils, trans., New York: Harcourt Brace, 1936).
45. *T&C*, pp. 365–6.
46. See Scott, J., *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven: Yale University Press, 1998); and Josephson, P., *Industrialized Nature* (Washington, D.C.: Shearwater Books, 2002) for interesting discussions and examples.
47. *ODM*, p. 79.

5 Labour and the lifeworld

1. See Hobbes, *Leviathan*, especially Chapter 5.
2. Lukács, G., *The Ontology of Social Being: 3: Labour* (Fernbach, trans., London: The Merlin Press, 1978).
3. *Ibid.*, p. 3.
4. Of course, we can look at a stone and consider it to be beautiful, but we would be departing from a materialist interpretation of the stone if we considered its beauty to be a property of the stone.
5. See *MEP*, Chapter 5, for further discussion of how natural laws are abstracted from the labour processes involved in experimentation, and how they are used in the ongoing development and testing of physical theories.
6. Lukács discussed the origin of this concept of freedom in the philosophical work of Hegel and Engels (*OSB*, pp. 120–6). It is also central to the philosophy of Bhaskar in *Dialectic: The Pulse of Freedom*.

7. For further discussion of the relation between geometry, art, and practical activity, see *MEP*.
8. This also explains how Kuhn's conception of a scientific revolution in terms of a paradigm shift is possible. The succeeding paradigm can emerge from the practices of the former, while developing autonomy from the former, to the extent that interpretations of the two paradigms become incommensurable.
9. *OSB*, p. 52.
10. Lukács noted that it should not be surprising that the naming of objects was taken by many ancient peoples as being a magical process of obtaining mastery over objects. Lukács used the Old Testament example of Adam naming the animals as a means of obtaining mastery over them. *OSB*, p. 101.
11. Thus people commonly represent themselves as engaging in a natural carnivorous activity when they eat a hamburger or a char grilled steak, rather than representing this act as being a social mediated product of artificially transforming the digestibility and appearance of carrion (by accelerating its decay through heating and creating its aesthetic form as a meal), which has been provided by other people in accordance with complex economic activities, relations, and institutions. Of course, raw meat is also a social product requiring socially developed, differentiated skilled practices and tools to kill and butcher a living animal in order to transform into cuts of raw meat. While hunting an animal also requires socially developed and differentiated skilled practices and weapons, this is even more complex when the animal has been farmed and is often a social product of domestication and selective breeding. In a modern society, only a small proportion of people have any immediate relation with the animals that are killed for food.
12. As Lukács pointed out (*OSB*, p. 110), magic, as a means of mastering forces of Nature or obtaining favours from gods, is itself based on a model of labour. Furthermore, following Engels, Lukács suggested that the suppression of the teleology of labour is bound up with the contempt for labour expressed by the ruling class, which no longer is involved in producing and reproducing the material conditions for their existence, and, thus, equates their own purposes and organisation of society with the rational principle of a cosmic, divine, or natural order of being.
13. *Technology and the Character of Contemporary Life*.
14. Borgmann, A., *Crossing the Postmodern Divide* (University of Chicago Press, 1992).
15. *Ibid*., p. 108.
16. Ihde, D., *Bodies in Technology* (Minneapolis: University of Minnesota, 2001).
17. Ihde was considerably influenced by Maurice Merleau-Ponty's concept of *praktognosia* as being pre-conscious, habitual, and practical knowledge that orders the motility and praxis of the body-subject without the need for reflection or mental representations (see *The Phenomenology of Perception*). This is a form of embodied knowledge that is unreflectively and unconsciously acquired through experience, habit, and non-verbal interpersonal communication (such as imitation and visualisation). This idea has considerable commonality with Michael Polanyi's concept of *tactic knowledge* (see *Personal Knowledge*).
18. *T&C*, p. 332.

19. *Ibid.*, p. 52.
20. Habermas, J., *Toward a Rational Society* (Shapiro, trans., Boston: Beacon Press, 1970).
21. Habermas, J., *The Theory of Communicative Action: Lifeworld and System: A Critique of Functionalist Reason* (McCarthy, trans., Boston: Beacon, 1984).
22. For an interesting discussion of this point, see Lie, M. and Sorensen, K., *Making Technology Our Own? Domesticating Technology Into Everyday Life* (Oslo: Scandinavian University Press, 1996).
23. *Toward a Rational Society*, p. 61.
24. Habermas, J., "Modernity – An Incomplete Project" (in Hal Foster, ed., *The Anti-Aesthetic*, Seattle, WA: By Press, 1983).
25. *The Poverty of Philosophy*, pp. 58–9.
26. *The Whale and the Reactor* (University of Chicago Press, 1986), p. 29.
27. *Autonomous Technology*.
28. Foucault, M., *Power/Knowledge: Selected Interviews and Other Writings 1972–1977* (Gordon, ed., New York: Pantheon, 1980).
29. *Ibid.*, p. 189.
30. *Ibid.*, p. 203.
31. *Ibid.*, pp. 212–13. Of course, even if we should condemn acts of revenge against members of the social elite, as being nothing more than pointless violent acts motivated by resentment and spite, it could well be argued that those people "at the top", who benefit most from society, have an ethical obligation to change the structures and mechanisms of power that reproduce social inequalities or at least refuse to participate in them. Even if these structures and mechanisms have been imposed on them from birth (as much as they have on those that are "beneath them"), it does not release them from their obligation to resist this imposition merely because they benefit from it more than others.
32. *Ibid.*, p. 98.
33. *Ibid.*, p. 214.
34. Feenberg, A., *Questioning Technology* (New York: Routledge, 1999), p. 79.
35. Feenberg frequently used Bijker's example of the bicycle to point out that the final design of the bicycle that we take for granted today was the result of a long, historical struggle between different social groups about the purpose of a bicycle, rather than a derivative product of an abstract technical rationality. While this is quite correct, in my opinion, it fails to acknowledge that a central feature of the bicycle is that it has two, circular wheels, and that there is a distinct, technical limit on the possibilities for any alternative design for a bicycle. Of course, it is possible to make a clown bicycle, with square or ovoid wheels of different size, and so on, but the reason why such a bicycle is funny is because it breaks with the technical limit of the design of an efficient and stable machine performance of a bicycle. Its humorousness is in direct proportion to the inefficiency and instability of its performance. To use another of Feenberg's favourite examples, it is clearly the case that human choices were involved in dealing with the problem of exploding boilers of the nineteenth-century American steamboats. This struggle between the politicians seeking votes, the boat owners seeking profits, the passengers seeking a means of safe travel, and crew seeking wages (and to live long enough to spend them) shows that

what constitutes "a safe boiler" design is bounded by socially defined situations and solutions. The design of a safe boiler is socially contingent, in so far that not only is every proposed design socially contingent, but the final choice is as well, as well as the need for such a design in the first place. However, minimal conditions for the design of a safe boiler are that it turns water into steam and does not explode. This does not mean that a boiler that has not exploded is a safe boiler, given that it might explode in the future, but it does mean that if it does not produce steam then it is not a working boiler, and any boiler that explodes is not a safe boiler. While the definition of the minimal conditions of the design of any machine are socially contingent, whether it satisfies those conditions is not determined only by social relations and contexts. Social construction theory ignores this asymmetry.

36. It is clear that Heidegger, Ellul, and Marcuse were all aware of this suppression of the contingency of human choices in the technological development of society. Feenberg's criticisms of Heidegger, Ellul, and Marcuse are very unfair because he accuses them of being essentialists and determinists about technology, when, in fact, it is quite obvious that they were concerned with a dominating tendency of modern technology, and all were aware that it does not have to be like this and alternatives are available to us. They simply disagreed on the alternatives.
37. *Questioning Technology*, p. 80.
38. Latour, B., "Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts" (in Bijker, W. and Law, J., eds, *Shaping Technology, Building Society: Studies in Sociotechnical Change*, Cambridge, Mass.: MIT Press), p. 232.

6 Into the future

1. I do not intend any connotation of human supremacism by this remark. I simply mean that a beast does not care about his or her future, only about his or her present. It is quite possible that there are many animals on Earth (or elsewhere) that also think about their future and try to find the best course of action in the absence of knowledge. In which case, they would also not be beasts either.
2. As Borgmann argued in *Technology and Contemporary Life*, pp. 114–24, the democratic and rational revaluation of technological innovation must be based upon a community engagement with the articulation and critical assessment of the concrete proposals of technology in contrast to the current conditions of their fullness, in accordance with considerations of sufficiency for a practical appraisal of the good life. See also Borgmann, A., "Communities of Celebration: Technology and Public Life" (in Ferré, ed., *Research in Philosophy and Technology*, vol. 10, Greenwich: JAI Press, 1990, pp. 315–45).
3. Hayek, F.A., *The Road to Serfdom* (New York: Routledge, 2001).
4. There are also obvious moral criticisms about the hypocrisy of the foundation of political and economic rationality of the American form of liberal capitalism, using the prosperity of the United States of America as evidence for the success of free-market individualism, when its wealth is historically

based upon the slavery of Africans and the theft of the land of the Native Americans.

5. See Herman, E.S. and Chomsky, N., *Manufacturing Consent: The Political Economy of the Mass Media* (New York: Pantheon Books, 1988); Chomsky, N., *Media Control: The Spectacular Achievements of Propaganda* (New York: Seven Stories Press, 2002); and Ellul, *Propaganda*, pp. 90–116 and pp. 232–50, for interesting and detailed discussions. Also, as Horkheimer and Adorno argued, in *Dialectic of Enlightenment*, the modern media ("the culture industry") has degenerated into the production of social conformity and mass entertainment.
6. Thus, Mumford considered the scientific and rational development of the technological basis of society to inevitably lead to communism (*T&C*, pp. 355–6). Mumford considered his conception of communism as essentially post-Marxist because he rejected the paleotechnic values upon which he considered Marxism to be based. After he expressed admiration for "soviet courage and discipline", he rejected the idea that communism needs to adopt the methods or take the political and institutional form proscribed by Marx, Lenin, Stalin, and the Soviet Union. He stated that his notion of communism – as a universal system for distributing the essential means of life – owed more to Plato than Marx (*T&C*, p. 403). He pointed out that within many modern societies schools, libraries, universities, museums, swimming pools, hospitals, sports facilities, and public parks are supported by and available to the community at large. Emergency services, such as police, fire, and ambulance, are already provided on the basis of need rather than ability to pay and, hence, likewise could be considered as basic communism. Also, even though it takes the form of welfare, a basic communism exists in most modern countries as far as provisions for the unemployed and the elderly is concerned.
7. The centralised and dictatorial Soviet Five-Year Plans were a good example of how a reduced stock of decision-makers were a structural handicap and antithetical to the whole social process of intelligent, flexible organisation of technological innovation within a complex and unpredictable world. After Stalin imposed the centralised plan to transform a backward feudal state into a modern industrialised state, the authoritarian and ideologically driven projects implemented by Soviet engineers and architects imposed their technologies upon local communities and workers without any knowledge about the conditions and complexities of the local situation and circumstances. Such a system was unable to develop in a flexible and intelligent way because it was unable (or unwilling) to take advantage of local knowledge. Thus centralisation resulted in inefficiency, waste, famine, and environmental catastrophes. As Vitaly Gorokhov argued, using the treatment of engineers in Stalin's USSR as an example, democracy is a condition for genuine scientific and technical progress because centralised planning fails to foresee all the details in advance and, hence, generates an anarchy of *diktats* and all the inefficiencies and self-deception that follows from this. See "Politics, Progress, and Engineering: Technical Professionals in Russia" (in Winner, L., ed., *Democracy in a Technological Society*, Dordrecht: Kluwer, 1992, pp. 175–85).

8. For detailed discussion of this point, see Feenberg, A., *Critical Theory of Technology* (New York: Oxford University Press, 1991), Chapters 2 and 6; Thomas, P., *Alien Politics: Marxist State Theory Revisited* (New York: Routledge, 1994); Cunningham, F., *Democratic Theory and Socialism* (Cambridge: Cambridge University Press, 1987).
9. *Toward a Rational Society*.
10. Barber, B., *Strong Democracy: Participatory Politics for a New Age* (Berkely, Calif.: University of California Press, 1984). Ellul (in "Technology and Democracy" in Winner, ed., *Democracy in a Technological Society*, pp. 35–50) also argued that there is an absence of democracy in Western political institutions, called for the abolition of the political class of professional politicians, and advocated the replacement of the current representative system in favour of a collective and participatory form of democracy among the general citizenry.
11. On this point, I very much agree with John Rawls, *A Theory of Justice* (Cambridge, MA: Harvard University Press, 1971), p. 61.
12. Feenberg, A., *Critical Theory of Technology* (New York: Oxford University Press, 1991). Feenberg rejected the dichotomy between technological rationality and humanist values implicit in the debate between instrumentalists and substantivists. He took this distinction from Borgmann's *Technology and the Character of Contemporary Life* (p. 9) and cited Nicholas Rescher and Emmanuel Mesthene as proponents of the instrumentalist theory of technology: that technology is a neutral means to rationally satisfy ends or goals established in other social spheres. See Rescher, N., "What is Value Change? A Framework for Research" (in K. Baier and N. Rescher, eds, *Values and the Future*, New York: The Free Press, 1969), and Mesthene, E., *Technological Change* (New York: Signet, 1970). He cited Ellul, Heidegger, Habermas, and Borgmann as proponents of the substantive theory of technology: that technology is an autonomous phenomenon, overriding all traditional or non-technical values, shaping both humanity and the natural world, and disseminating and transforming ends and goals, as both an environment and way of life.
13. Sclove, R.E., *Democracy and Technology* (New York: Guildford Press, 1995).
14. *Ibid*., Chapter 7.
15. *Ibid*., p. 160.
16. Colin Ward, in *Housing: An Anarchist Approach* (London: Freedom Press, 1983), also made a similar case for participatory, local democracy in the development of urban neighbourhoods.
17. Milton Friedman, *Capitalism and Freedom* (University of Chicago Press, 1962), in his defence of "free market" globalisation, claimed that the globalisation of the market makes prejudice meaningless and obsolete. He quipped (p. 109) "The purchaser of bread does not know whether it was made from wheat grown by a white man or a Negro, by a Christian or a Jew." But, in my view, the problem is that when the process by which wheat is grown and made into bread is completely anonymous and abstract, the purchaser of bread simply does not care where it came from or how it was made. It becomes a product that comes into existence only at the moment that it is picked off the supermarket shelf. Globalisation generates an indifference to the material and social conditions for the production of our food. It allows us to be content to be ignorant about the conditions upon which our lives

are made possible, which is understandable, because once we are aware of the terrible conditions under which most of the people who grow our wheat in the Third World live and work, as well as the pittance that they are paid for their backbreaking efforts, then the bread becomes increasingly hard to swallow. Our only alternative to blissful ignorance is to develop callousness towards others as a precondition for our pleasure in our food.

18. *Democracy and Technology*, p. 85.
19. *Ibid.*, p. 204.
20. *Ibid.*, p. 104.
21. For further discussion of this point, see Harrison, P., *The Greening of Africa: Breaking Through the Battle for Land and Food* (London: Paladin Grafton Books, 1987); and Appfel-Marglin, F. and Marglin, S., eds, *Decolonising Knowledge: From Development to Dialogue* (Oxford: Clarendon Press, 1996).
22. *D&T*, p. 193.
23. See Dickson, D., *Alternative Technology and the Politics of Technological Change* (Collins, 1974) and *The New Politics of Science* (University of Chicago Press, 1984) for interesting and detailed discussion of the way that civic, military, and commercial ambitions have dominated the directions of science and technology since the end of the Second World War. See Frost, R.L., "Mechanical Dreams in Twentieth-Century France" (in Winner, ed., *Democracy in a Technological Society*, pp. 51–77), for a discussion of how French nuclear technology was developed as a symbol of national greatness, rather than simply a means of electricity supply. See also Myklebust, S., ed., *Technology and Democracy: Obstacles to Democratisation – Productivism and Technocracy* (Oslo: Centre for Technology and Culture, 1997); Postman, N., *Technopoly: The Surrender of Culture to Technology* (New York: Vintage Books, 1992); and Day, R.B., Beiner, R., and Masciulli, J., eds, *Democratic Theory and Technological Society* (Armonic, N.Y.: Sharpe, 1988), for further discussions, examples, and references.
24. See *The Whale and the Reactor*, Chapter 2; also, see *Autonomous Technology*.
25. *D&T*, p. 81.
26. *Ibid.*, p. 183.
27. Sassower, R., *Confronting Disaster: An Existential Approach to Technoscience* (Oxford: Lexington Books, 2004), pp. 72–3.
28. Winner, *Democracy in a Technological Society*, p. 15.
29. As C.P. Snow argued, in *Two Cultures and a Second Look* (Cambridge University Press, 1964), it is essential that we get beyond the "two cultures" science or humanities track education system. In *The Human Condition*, Hannah Arendt was critical of the ambition of technological science "to escape the human condition" instead of remaining philosophically related to it through a thinking relation with labour. Due to its increasing specialisation of technical and mathematical language, she argued that scientists and technologists increasingly "move in a world where speech has lost its power", where technology and thinking have "parted company for good" (p. 3).
30. *D&T*, p. 53.
31. See Ellul's discussion of this point in "Technology and Democracy" (in Winner, ed., *Democracy in a Technological Society*), pp. 43–4.
32. "Populism and the Cult of the Expert" (in Winner, ed., *Democracy in a Technological Society*, pp. 91–103).

33. *D&T*, p. 49.
34. *T&C*, p. 426.
35. *Ibid*., p. 429.
36. Hughes, T.P., *Human-Built World: How To Think About Technology and Culture* (University of Chicago Press, 2004). See also Spirn, A., *The Granite Garden: Urban Nature and Human Design* (New York: Basic Books, 1984).
37. Hughes, *Human-Built World*, pp. 16–43. Miller, P., ed., *Errand into the Wilderness* (Cambridge, Mass.: Belknap Press, 1956); Thomas Jefferson, *Notes on the State of Virginia* (1785); Robert Beverly, *History and the Present State of Virginia* (1705); J.A. Etzler, *The Paradise Within the Reach of all Men, Without Labour, by the Powers of Nature and Machinery* (1836); and, Ralph Waldo Emerson, *Nature* (1836).
38. *HBW*, p. 153.

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