Technology Matters

Matters

QUESTIONS
TO LIVE WITH

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Preface

Technology matters because it is inseparable from being human. Devices and machines not things "out there" that invade life. We are intimate with them from birth, as were our ancestors for hundreds of generations. Like most children born in the twentieth century, I played with technological toys—miniature trucks, cars, stoves, airplanes, and railroads and full-size fake guns, swords, and telephones. With such toys I built castles, reshaped landscapes, put out imaginary fires, fought blood-less wars, and prepared imaginary food. Children learn to conceive technological solutions to problems, and in doing so they shape their own imaginations. Computer games add new dimensions to this process, but the fundamental point remains the

same: By playing with technological toys, boys and girls imagine themselves into a creative relationship with the world. For a few people, playful imitation leads directly to a life's work as a fireman, an architect, a truck driver, a pilot, a soldier, a cook, a farmer, or a mechanic. These people are exceptions. Yet as adults many people retain their technological playfulness, expressing it in the acquisition of new appliances, gadgets, software, car accessories, and sports equipment. We live not merely in a technological world, but in a world that from our earliest years we imagine and construct through tools and machines.

Yet we seldom think systematically about the machines and systems that surround us. Do they shape us, or we them? How is our relationship to them changing? Are machines in the saddle, or will they soon be? Do they enrich us, or impoverish us? Are we using them more to destroy the natural world, or more to protect it? To undermine democracy, or to enhance it? To homogenize cultural differences, or increase them? To make the world more secure, or more dangerous? These are some of the questions that led me to write this book. I examine some of the more persuasive answers, but I can provide only provisional solutions. As with all large issues, technological questions resist final answers. When a young poet wrote to Rainer Maria Rilke that he had lost his faith in God, Rilke famously replied: ". . . be patient toward all that is unsolved in your heart and try to love the questions themselves like locked rooms and like books that are written in a very foreign tongue. . . . Live the questions now. Perhaps you will then gradually, without noticing it, live along some distant day into the answers." (Letters to a Young Poet, revised edition, Norton, 1954, p. 35)

I am asking readers of this book to recognize and wrestle with technological questions. The toys of childhood gave us easy solutions to imaginary problems. As adults, we see the complexity of technology, including its side effects and its unintended consequences as well as its benefits. Like it or not, we must live along until the day when we can understand technology better.

I devote a chapter each to the following questions, which I consider central and unavoidable:

- What is technology?
- Is technology inherently deterministic, or is it inflected or even shaped by culture?
- Is technology predictable?
- How do historians understand technology?
- Does using modern technologies break down cultural differences, or does it increase them?
- What is the relationship between technology and nature?
- Do new technologies destroy jobs, or do they create new opportunities?
- How should societies choose new technologies?
- Should "the market" decide?
- Do advanced technologies make life more secure, or do they expose humanity to escalating dangers?
- Does increasing use of technologies expand mental horizons, or does it encapsulate human beings in artifice?

This book aims to help people think about life in an intensely technological world. It addresses general questions that ordinary people ask but specialists often overlook. Scholars, understandably, prefer to avoid such large, general questions and instead to work on clearly defined, manageable subjects. Since it is hard to give de-

finite answers to these big questions, it is safer not to attempt to do so. Yet these large and perhaps unanswerable questions are important. So this book is not necessarily for specialists; it is for anyone who has wondered about such things. My answers are provisional, until readers find better ones.

Acknowledgements

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1 Can We Define "Technology"?

One way to define "technology" is in terms of evolution. An animal may briefly use a natural object, such as a branch or a stone, for a purpose, but it was long thought that only human beings intentionally made objects, such as a rake or a hammer, for certain functions. Benjamin Franklin and many others thought that tool use separated humans from all other creatures. Recent fieldwork complicates the picture. Jane Goodall watched a chimpanzee in its own habitat. It found a twig of a certain size, peeled off its bark, looked for a termite hill, thrust in the peeled twig, pulled it out covered with termites, and ate them. This chimpanzee not only made a tool, it did so with forethought. In 2004, scientists announced discovery of the bones of a previously unknown species in an Indonesian cave. Standing only three feet high, this dwarf species lived and used tools as recently as 12,000 years ago.[1] Yet if Franklin's idea needs modification, it seems that only intelligent apes and human species are toolmakers, while the vast majority of animals are not. Birds construct nests. Beavers cut down trees and build dams. Ants and bees build complex communities that include a division of labor and food storage. But only a few species have made tools. Notable is a hand axe widely used by *Homo erectus* 1.6 million years ago.

Homo sapiens have used tools for at least 400,000 years, and seem to have done so from their first emergence. Technologies are not foreign to "human nature" but inseparable from it. Our ancestors evolved an opposition between thumb and fingers that made it easier to grasp and control objects than it is for other species. Indeed, prehensile hands may even have evolved simultaneously with the enlarging human cortex. Learning to use tools was a crucial step in the species' development, both because it increased adaptability and because it led to a more complex social life. Using tools, the relatively weak *Homo sapiens* were able to capture and domesticate animals, create and control fire, fashion artifacts, build shelters, and kill large animals. Deadly tools also facilitated murder and warfare. Tools emerged with the higher apes, and one might argue that humanity fashioned itself with tools.[2]

The central purpose of technologies has not been to provide necessities, such as food and shelter, for humans had achieved these goals very early in their existence. Rather, technologies have been used for social evolution. "Technology," José Ortega y Gasset argued, "is the production of superfluities—today as in the Paleolithic age. That is why animals are atechnical; they are content with the simple act of living."[3] Humans, in contrast, continually redefine their necessities to include more. Necessity is often not the mother of invention. In many cases, it surely has been just the opposite, and invention has been the mother of necessity. When humans possess a tool, they excel at finding new uses for it. The tool often exists before the problem to be solved. Latent in every tool are unforeseen transformations.

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[1] "Ancient hobbit-sized human species discovered," Associated Press, October 27, 2004.

[2] I will not try to make this argument, but some scholars contend that the brain developed in interaction with tool use and therefore should be considered a human technology. See e.g. Beniger 1986, p. 9.

[3] José Ortega y Gasset, "Man the Technician," in Ortega y Gasset 1941, p. 100.

Defining technology as inseparable from human evolution suggests that tools and machines are far more than objects whose meaning is revealed simply by their purposes. As the great stone circle at Stonehenge reminds us, they are part of systems of meaning, and they express larger sequences of actions and ideas. Ultimately, the meaning of a tool is inseparable from the stories that surround it. Consider the similarity between what is involved in creating and using a tool and the sequence of a narrative. Even the chimpanzee picking up and peeling a twig to "fish" for termites requires the mental projection of a sequence, including an initial desire, several actions, and successful feeding. The sequence becomes more complex when more tools are involved, or when the same tool is used in several ways. Composing a narrative and using a tool are not identical processes, but they have affinities. Each requires the imagination of altered circumstances, and in each case beings must see themselves to be living in time. Making a tool immediately implies a succession of events in which one exercises some control over outcomes. Either to tell a story or to make a tool is to adopt an imaginary position outside immediate sensory experience. In each case, one imagines how present circumstances might be made different.

When faced with an inadvertently locked automobile with the keys inside, for example, one has a problem with several possible solutions—in effect, a story with several potential endings. One could call a locksmith, or one could use a rock to break one of the car's windows. Neither is as elegant a solution as passing a twisted coat hanger through a slightly open window and lifting the door handle from the inside. To improvise with tools or to tell stories requires the ability to imagine not just one outcome but several. To link technology and narrative does not yoke two disparate subjects; rather, it recalls an ancient relationship.

Tools are older than written language (perhaps, as the chimpanzee's "fishing stick" suggests, even older than spoken language) and cannot merely be considered passive objects, or "signifieds." Tools are known through the body at least as much as they are understood through the mind. The proper use of kitchen utensils and other tools is handed down primarily through direct observation and imitation of others using them. Technologies are not just objects but also the skills needed to use them. Daily life is saturated with tacit knowledge of tools and machines. Coat hangers, water wheels, and baseball bats are solid and tangible, and we know them through physical experiences of texture, pressure, sight, smell, and sound during use more than through verbal description. The slightly bent form of an American axe handle, when grasped, becomes an extension of the arms. To know such a tool it is not enough merely to look at it: one must sense its balance, swing it, and feel its blade sink into a log. Anyone who has used an axe retains a sense of its heft, the arc of its swing and its sound. As with a baseball bat or an axe, every tool is known through the body. We develop a feel for it. In contrast, when one is only looking at an axe, it becomes a text that can be analyzed and placed in a cultural context. It can be a basis for verifiable statements about its size, shape, and uses, including its incorporation into literature and art. Based on such observations, one can construct a chronology of when it was invented, manufactured, and marketed, and of how people incor-

porated it into a particular time and place. But "reading" the axe yields a different kind of knowledge than using it.

Telling stories and using tools are hardly identical, but there are similarities. Each involves the organization of sequences, either in words or in mental images. For another investigation it might be crucial to establish whether tools or narratives came first, but for my argument it matters only that they emerged many millennia ago. I do not propose to develop a grand theory of how human consciousness evolved in relation to tools. But the larger temporal framework is a necessary reminder that tools existed long before written texts and that tools have always embodied latent narratives. My definition of technology does not depend on fixing precisely when humans began to use tools, although it is pertinent that they did so thousands of years before anyone developed tools for writing. Cultures always emerge before texts. Long before the advent of writing, every culture had a system of artifacts that evolved together with spoken language. Objects do not define words, or vice-versa; both are needed to construct a cultural world. Only quite late in human development did anyone develop an alphabet, a stylus to mark clay tablets, or a quill adapted for writing on paper. Storytelling was oral for most of human history.

A tool always implies at least one small story. There is a situation; something needs doing. Someone obtains or invents a tool in order to do it—a twisted coat hanger, for example. And afterwards, when the car door is opened, there is a new situation. Admittedly, this is not much of a narrative, taken in the abstract, but to conceive of a tool is to think in time and to imagine change. The existence of a tool also immediately implies that a cultural group has reached a point where it can remember past actions and reproduce them in memory. Tools require the ability to recollect what one has done and to see actions as a sequence in time. To explain what a tool is and how to use it seems to demand narrative. Which came first? This may be a misleading question. It seems more likely that storytelling and toolmaking evolved symbiotically, analogous to the way that oral performances are inseparable from gestures and mimicry.

It is easy to imagine human beings as pre-literate, but it is difficult to imagine them as pre-technological. Most Native American peoples, for example, did not write, but they did develop a wide range of tools, including snowshoes, traps, tents, drums, hatchets, bows, pottery, ovens, bricks, canals, and irrigation systems. All social groups use tools to provide music, shelter, protection, and food, and these devices are inseparable from verbal, visual, and kinetic systems of meaning. Each society both invents tools and selects devices from other cultures to establish its particular technological repertoire of devices.

In Herman Melville's *Moby Dick*, Queequeg, a South Sea harpooner visiting Nantucket, was offered a wheelbarrow to move his belongings from an inn to the dock. But he did not understand how it worked, and so, after putting all his gear into the wheelbarrow he lifted it onto his shoulders. Most travelers have done something that looked equally silly to the natives, for we are all unfamiliar with some local technologies. This is another way of saying that we do not know the many routines and small narratives that underlie everyday life in other societies.

As the evolutionary perspective shows, technology is not something new; it is more ancient than the stone circles at Stonehenge. Great stone blocks, the largest weighing up to 50 tons, rise out of the Salisbury Plain, put precisely into place in roughly 2000 B.C. The stones were not quarried nearby, but transported 20 miles from Marlborough Down. The builders contrived to situate them in a pattern of alignment that still registers the summer solstice and some astronomical events. The builders acquired many technologies before they could construct such a site. Most obviously, they learned to cut, hoist, and transport the stones, which required ropes, levers, rollers, wedges, hammers, and much more. Just as impressive, they observed the heavens, somehow recorded their observations, and designed a monument that embodied their knowledge. They did not leave written records, but Stonehenge stands as an impressive text from their culture, one that we are still learning to read. Transporting and placing the massive stones can only be considered a technological feat. Yet every arrowhead and potshard makes a similar point: that human beings mastered technologies thousands of years ago. Stonehenge suggests the truth of Walter Benjamin's observation that "technology is not the mastery of nature but of the relations between nature and man."[4]

Technologies have been part of human society from as far back as archaeology can take us into the past, but "technology" is not an old word in English. The ancient Greeks had the word "techne," which had to do with skill in the arts. Plato and Plotinus laid out a hierarchy of knowledge that stretched in an ascending scale from the crafts to the sciences, moving from the physical to the intellectual. The technical arts could at best occupy a middle position in this scheme. Aristotle had a "more neutral, simpler and far less value-laden concept of the productive arts."[5] He discussed "techne" in the *Nicomachean Ethics*[6] (book 6, chapters 3 and 4). Using architecture as his example, he defined art as "a rational faculty exercised in making something . . . a productive quality exercised in combination with true reason." "The business of every art," he asserted, "is to bring something into existence." A product of art, in contrast to a product of nature, "has its efficient cause in the maker and not in itself."[7] Such a definition includes such actions as making pottery, building a bridge, and carving a statue. Just as important, Aristotle related the crafts to the sciences, notably through mathematics. In Greek thought as a whole, however, work with the hands was decidedly inferior to philosophical speculation, and "techne" was a more restricted term than the capacious modern term "technology." Perhaps because the term was more focused, classical thinkers realized, Leo Strauss wrote, "that one cannot be distrustful of political or social change without being distrustful of technological change."[8] As Strauss concluded, they "demanded the strict moral-political supervision of inventions; the good and wise city will

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[4] Benjamin 1986, p. 93.
[5] Whitney 1990, pp. 50–51.
[6] Aristotle, *Nicomachean Ethics*, book 6, chapters 3 and 4.
[7] *The Ethics of Aristotle* (Penguin Classics, 1953), p. 175.
[8] Strauss 1959, p. 298.

determine which inventions are to be made use of and which are to be sup-pressed."[9]

The Romans valued what we now call technology more highly than the Greeks. In *De Natura Deorum* Cicero praised the human ability to transform the environment and create a "second nature." Other Roman poets praised the construction of roads and the pleasures of a well-built villa. Statius devoted an entire poem to praising technological progress, and Pliny authored prose works with a similar theme.[10] Saint Augustine synthesized Plato and Aristotle with Cicero's appreciation of skilled labor: ". . . there have been discovered and perfected, by the natural genius of man, innumerable arts and skills which minister not only to the necessities of life but also to human enjoyment. And even in those arts where the purposes may seem superfluous, perilous and pernicious, there is exercised an acuteness of intelligence of so high an order that it reveals how richly endowed our human nature is."[11] In contrast, Thomas Aquinas characterized the mechanical arts as merely servile.[12] Some medieval thinkers, notably Albertus Magnus, appreciated iron smelting, the construction of drainage ditches, and the new plowing techniques that minimized erosion. A few drew upon Arabic thought, which presented the crafts as practical science and applied mathematics. Roger Bacon, in his *Communia Mathematica*, imagined flying machines, self-propelled vehicles, submarines, and other conquests of nature. Bacon put so much emphasis on the practical advantages of experiment and construction of useful objects that he "came close to reversing the usual hierarchy of the speculative and useful in medieval thought."[13]

The full expression of a modern attitude toward technology appeared only centuries later, during the Renaissance, notably in Francis Bacon's *New Atlantis* (1627). Bacon imagined a perfect society whose king was advised by scientists and engineers organized into research groups at an institution called Saloman's House. They could predict the weather, and they had invented refrigeration, submarines, flying machines, loudspeakers, and dazzling medical procedures. Their domination of nature, which had no sinister side effects, satisfied material needs, abolished poverty, and eliminated injustice. This vision helped to inspire others to found the Royal Society.[14] Established in London in 1662, this society institutionalized the belief that science and invention were the engines of progress. The Royal Society proved to be a permanent body, in contrast to earlier, temporary groups that could also be seen as originators of modern research, such as those gathered in Tycho Brahe's astronomical observatory on an island near Copenhagen, or Emperor Rudolf's group of technicians and scientists in Prague.

Today, a large bookstore typically devotes a section to the history of science but scatters books on technological history through many departments, including

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[9] Ibid.

[10] Pavlovskis 1973, pp. 20 and 33, passim.

[11] Cited on p. 52 of Whitney 1990.

[12] Whitney 1990, pp. 139– 140.

[13] Ibid., pp. 143– 145.

[14] Sibley 1973, p. 264. See also Wallace 2003, pp. 11– 21.

sociology, cultural studies, women's studies, history, media, anthropology, transportation, and do-it-yourself. The fundamental misconception remains that practical discoveries emerge from pure science and that technology is merely a working out or an application of scientific principles. In fact, for most of human history technology came first; theory came along later and tried to make sense of practical results. A metallurgist at MIT, Cyril Stanley Smith, who helped design the first atomic bombs at Los Alamos, declared: "Technology is more closely related to art than to science—not only materially, because art must somehow involve the selection and manipulation of matter, but conceptually as well, because the technologist, like the artist, must work with unanalyzable complexities."[15] Smith did not mean that these complexities are forever unanalyzable; he meant that at the moment of making something a technologist works within constraints of time, knowledge, funding, and the materials available. It is striking that he advances this argument when discussing the construction of the first atomic bomb, which might seem to be the perfect example of an object whose possibility was deduced from pure science alone. However, Smith is correct to emphasize that the actual design of a bomb required far more than abstract thinking, particularly an ability to work with tools and materials. In fact, one sociologist of science has concluded that, although we cannot turn back the clock and "unlearn" the science that lies behind nuclear weapons, it is conceivable that we will manage to lose or forget the practical skills needed to make them.[16]

As Smith further pointed out, technology's connection to science is generally misunderstood: "Nearly everyone believes, falsely, that technology is applied science. It is becoming so, and rapidly, but through most of history science has arisen from problems posed for intellectual solution by the technician's more intimate experience of the behavior of matter and mechanisms."[17] Often the use of tools and machines has preceded a scientific explanation for how they work or why they fail. Thomas Newcomen, who made the first practical steam engines in Britain, worked as an artist in Aristotle's sense of the term "techne." He conceivably might have heard that a French scientist, Denis Papin, was studying steam and vacuum pumps. However, Newcomen had little formal education and could not have read Papin's account of his experiments, published in Latin (1690) or in French (1695), though he conceivably could have seen a short summary published in English (1697). He never saw Papin's small laboratory apparatus—and even had he seen it, it would not have been a model for his much larger engine. Newcomen's steam engine emerged from the trial and error of practical experiments. Papin's scientific publications were less a basis for inventing a workable steam engine than a theoretical explanation for how a steam engine worked. However, further improvements in the steam engine did call for more scientific knowledge on the part of James Watt and later inventors. Likewise, Thomas Edison built his electrical system without the help of mathematical equations to explain the behavior of electricity. Later, Charles Steinmetz

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[15] Cyril Stanley Smith, cited on p. 331 of Rhodes 1999.

[16] MacKenzie 1998.

[17] Smith, cited on p. 331 of Rhodes 1999.

and others developed the theoretical knowledge that was necessary to explain the system mathematically and refine it, but this was after Edison's laboratory group had invented and marketed all the components of the electrical system, including generators, bulbs, sockets, and a wiring system. Science has played a similar role in the refinement of many technologies, including the windmill, the water wheel, the locomotive, the automobile, and the airplane.[18] The Wright Brothers were well-read and gifted bicycle mechanics, and they tested their designs in a wind tunnel of their own invention, but they were not scientists.[19]

If one bears these examples in mind, the emergence of the term "technology" into English from modern Latin in the seventeenth century makes considerable sense. At first, the term was almost exclusively employed to describe a systematic study of one of the arts. A book might be called a "technology" of glassmaking, for example. By the early eighteenth century, a characteristic definition was "a description of the arts, especially the mechanical." The word was seldom used in the United States before 1829, when Jacob Bigelow, a Harvard University professor, published a book titled *Elements of Technology*.[20] As late as the 1840s, almost the only American use of the word was in reference to Bigelow's book.[21] In 1859, the year before he was elected president, Abraham Lincoln gave several versions of a lecture on discoveries and inventions without once using the word.[22] Before 1855, even *Scientific American* scarcely used "technology," which only gradually came into circulation. Instead, people spoke of "the mechanic arts" or the "useful arts" or "invention" or "science" in contexts where they would use "technology" today. A search of prominent American periodicals shows that between 1860 and 1870 "technology" appeared only 149 times, while "invention" occurred 24,957 times. During the nineteenth century the term became embedded in the names of prominent educational institutions such as the Massachusetts Institute of Technology, but it had not yet become common in the discussion of industrialization.[23] "At the time of the Industrial Revolution, and through most of the nineteenth century," Leo Marx writes, "the word *technology* primarily referred to a kind of book; except for a few lexical pioneers, it was not until the turn of [the twentieth] century that sophisticated writers like Thorstein Veblen began to use the word to mean the mechanic arts collectively. But that sense of the word did not gain wide currency until after World War I."[24]

This broader definition owed much to German, which had two terms: "teknologie" and the broader "technik." In the early twentieth century, "technik"

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[18] Don Ihde, "The historical-ontological priority of technology over science," in Ihde 1983.

[19] On the Wright Brothers, see Tobin 2003.

[20] Bigelow 1840.

[21] This statement is based on a survey of 100,000 nineteenth-century journal articles in Cornell University's electronic archive "Making of America" (available at http://moa.cit.cornell.edu/moa/index.html). Before 1840 there are only 34 uses of the term, all but three either in writings by Bigelow or in references to them. Two referred to curricula in German universities, and the last was an eccentric usage in a legal context that seems unrelated to machines.

[22] Abraham Lincoln, "Second Lecture on Discoveries and Inventions," in *Collected Works of Abraham Lincoln*, volume 3, ed. R. Brasler (Rutgers University Press, 1953–55), pp. 357–358.

[23] Oldenziel 2003.

[24] Marx 1997.

was translated into English as "technics."[25] From roughly 1775 until the 1840s, "teknologie" referred to systems of classification for the practical arts, but it was gradually abandoned. During the later nineteenth century, German engineers made "technik" central to their professional self-definition, elaborating a discourse that related the term to philosophy, economics, and high culture. "Technik" meant the totality of tools, machines, systems and processes used in the practical arts and engineering.[26] Both Werner Sombart and Max Weber used the term extensively, influencing Thorstein Veblen and others writing in English. As late as 1934, Lewis Mumford's landmark work *Technics and Civilization* echoed this German usage. However, Mumford also used the term "technology" not in the narrow Germanic sense but in reference to the sum total of systems of machines and techniques that underlie a civilization. In subsequent decades the term "technics" died out in English usage and its capacious meanings were poured into "technology."[27]

Mumford had these larger meanings and the German tradition in mind when he argued that three fundamentally different social and economic systems had succeeded one another in an evolutionary pattern. Each had its own "technological complex." He called these "eotechnic" (before c. 1750), "paleotechnic" (1750– 1890), and "neotechnic" (1890 on). Mumford conceived these as overlapping and interpenetrating phases in history, so that their dates were approximate and varied from one nation to another. Each phase relied on a distinctive set of machines, processes, and materials. "Speaking in terms of power and characteristic materials," Mumford wrote, "the eotechnic phase is a water-and-wood complex, the paleotechnic phase is a coal-and-iron complex, and the neotechnic phase is an electricity-and-alloy complex."[28] Although historians no longer use either Mumford's terms or his chronology, the sense that history can be conceived as a sequence of technical systems has become common. Along with this sense of a larger sequence came the realization that machines cannot be understood in isolation. As Mumford put it: "The machine cannot be divorced from its larger social pattern; for it is this pattern that gives it meaning and purpose."[29]

One important part of this pattern that Mumford missed, however, was how thoroughly "technology" was shaped by gender. For example, legal records from the thirteenth and fourteenth centuries show that in rural England women were entirely responsible for producing ale, the most common drink of the peasantry. Men took control of alemaking only when it was commercialized.[30] Similarly, some scholars argue that in the early medieval era European women worked in many trades, but that in early modern times women were gradually displaced by men.[31] Ruth Oldenziel has persuasively extended such arguments into the twentieth century, showing that Western society only relatively recently

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25 Schatzberg, "Technik Comes to America."

26 Ibid.

27 Ibid.

28 Mumford 1934, p. 110.

29 Ibid., p. 100.

30 Bennett 1996.

31 Herlihy 1990, pp. 75– 97.

defined the word "technology" as masculine. Between 1820 and 1910, as the word acquired its present meaning, it acquired male connotations. Before then, "the useful arts" included weaving, potterymaking, sewing, and any other activity that transformed matter for human use. The increasing adoption of the word "technology," therefore, is not simply a measure of the rise of industrialization. It also measures the marginalization of women.[32] In the United States, women were excluded from technical education at the new university-level institutes, such as the Rensselaer Polytechnic Institute (established in 1824) and the Massachusetts Institute of Technology (founded in 1861). Nevertheless, because one could become an engineer on the basis of job experience, there were several thousand female engineers in the United States during the nineteenth century. Likewise, despite many obstacles, there were female inventors. The women's buildings of the great world's fairs in Philadelphia (1876), Chicago (1893), Buffalo (1901), and St. Louis (1904) highlighted women's inventions and their contributions to the useful arts. Furthermore, even though women had been almost entirely excluded from formal engineering education, many worked as technical assistants in laboratories, hospitals, and factories. Engineering was culturally defined as purely masculine, pushing women to the margins or to subordinate positions. Only in recent years have scholars begun to see technology in gendered terms, however, and this realization is not yet widely shared.

Indeed, the meaning of "technology" remained unstable in the second half of the twentieth century, when it evolved into an annoyingly vague abstraction. In a single author's writing, the term could serve as both cause and effect, or as both object and process. The word's meaning was further complicated in the 1990s, when newspapers, stock traders, and bookstores made "technology" a synonym for computers, telephones, and ancillary devices. "Technology" remains an unusually slippery term. It became a part of everyday English little more than 100 years ago. For several hundred years before then, it meant a technical description. Then it gradually became a more abstract term that referred to all the skills, machines, and systems one might study at a technical university. By the middle of the twentieth century, technology had emerged as a comprehensive term for complex systems of machines and techniques.

Indeed, some thinkers began to argue that these systems had a life and a purpose of their own, and no sooner was "technology" in general use than some began to argue for "technological determinism." A single scene in Stanley Kubrick's film *2001* captures the essence of this idea. A primitive ancestor of modern man picks up a bone, uses it as a weapon, then throws it into the air, where it spins, rises, and metamorphoses into a space station. The implications of this scene were obvious: a direct line of inevitable technological development led from the first tools to the conquest of the stars. Should we accept such determinism?

32 Oldenziel 1999.