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## Perceptions of technology

### Science and technology

Among the insights that arise from this review of the history of [technology](#) is the light it throws on the distinction between science and technology. The history of technology is longer than and distinct from the [history of science](#). Technology is the systematic study of techniques for making and doing things; science is the systematic attempt to understand and interpret the world. While technology is concerned with the fabrication and use of [artifacts](#), science is devoted to the more [conceptual](#) enterprise of understanding the [environment](#), and it depends upon the comparatively sophisticated skills of literacy and numeracy. Such skills became available only with the emergence of the great world civilizations, so it is possible to say that science began with those civilizations, some 3,000 years bce, whereas technology is as old as humanlike life. Science and technology developed as different and separate activities, the former being for several millennia a field of fairly [abstruse](#) speculation practiced by a class of aristocratic philosophers, while the latter remained a matter of essentially practical concern to craftsmen of many types. There were points of intersection, such as the use of mathematical concepts in building and irrigation work, but for the most part the functions of scientist and technologist (to use these modern terms retrospectively) remained distinct in the ancient [cultures](#).

The situation began to change during the [medieval](#) period of development in the West (500–1500 ce), when both technical [innovation](#) and scientific understanding interacted with the stimuli of commercial expansion and a flourishing [urban culture](#). The [robust](#) growth of technology in these centuries could not fail to attract the interest of educated men. Early in the 17th century the natural philosopher [Francis Bacon](#) recognized three great technological innovations—the magnetic compass, the [printing press](#), and gunpowder—as the distinguishing achievements of modern man, and he advocated experimental science as a means of enlarging man’s dominion over nature. By emphasizing a practical role for science in this way, Bacon implied a harmonization of science and technology, and he made his intention explicit by urging scientists to study the methods of craftsmen and urging craftsmen to learn more science. Bacon, with Descartes and other contemporaries, for the first time saw man becoming the master of nature, and a convergence between the traditional pursuits of science and technology was to be the way by which such mastery could be achieved.

Yet the wedding of science and technology proposed by Bacon was not soon [consummated](#). Over the next 200 years, carpenters and mechanics—practical men of long standing—built iron bridges, steam engines, and [textile machinery](#) without much reference to scientific principles, while scientists—still amateurs—pursued their investigations in a haphazard manner. But the body of men, inspired by Baconian principles, who formed the [Royal Society](#) in London in 1660 represented a determined effort to direct scientific research toward useful ends, first by improving navigation and [cartography](#), and ultimately by stimulating industrial innovation and

the search for mineral resources. Similar bodies of scholars developed in other European countries, and by the 19th century scientists were moving toward a professionalism in which many of the goals were clearly the same as those of the technologists. Thus, [Justus von Liebig](#) of Germany, one of the fathers of organic chemistry and the first proponent of mineral fertilizer, provided the scientific impulse that led to the development of [synthetic](#) dyes, high explosives, artificial fibres, and plastics, and [Michael Faraday](#), the brilliant British experimental scientist in the field of electromagnetism, prepared the ground that was exploited by [Thomas A. Edison](#) and many others.

The role of Edison is particularly significant in the deepening relationship between science and technology, because the prodigious trial-and-error process by which he selected the carbon filament for his electric lightbulb in 1879 resulted in the creation at Menlo Park, N.J., of what may be regarded as the world's first genuine industrial research laboratory. From this achievement the application of scientific principles to technology grew rapidly. It led easily to the [engineering](#) rationalism applied by [Frederick W. Taylor](#) to the organization of workers in [mass production](#), and to the time-and-motion studies of Frank and Lillian Gilbreth at the beginning of the 20th century. It provided a model that was applied rigorously by [Henry Ford](#) in his automobile assembly plant and that was followed by every modern mass-production process. It pointed the way to the development of [systems engineering](#), [operations research](#), simulation studies, mathematical modeling, and technological [assessment](#) in industrial processes. This was not just a one-way influence of science on technology, because technology created new tools and machines with which the scientists were able to achieve an ever-increasing insight into the natural world. Taken together, these developments brought technology to its modern highly efficient level of performance.

## Criticisms of technology

Judged entirely on its own traditional grounds of evaluation—that is, in terms of efficiency—the achievement of modern technology has been admirable. Voices from other fields, however, began to raise disturbing questions, grounded in other modes of evaluation, as technology became a dominant influence in society. In the mid-19th century the non-technologists were almost unanimously enchanted by the wonders of the new [man-made environment](#) growing up around them. London's Great Exhibition of 1851, with its arrays of machinery housed in the truly innovative [Crystal Palace](#), seemed to be the culmination of Francis Bacon's prophetic forecast of man's increasing dominion over nature. The new technology seemed to fit the prevailing laissez-faire economics precisely and to guarantee the rapid realization of the [Utilitarian](#) philosophers' ideal of "the greatest good for the greatest number." Even [Marx](#) and Engels, espousing a radically different political orientation, welcomed technological progress because in their eyes it produced an [imperative](#) need for socialist ownership and control of [industry](#). Similarly, early exponents of [science fiction](#) such as [Jules Verne](#) and H.G. Wells explored with zest the future possibilities opened up to the optimistic imagination by modern technology, and the American utopian [Edward Bellamy](#), in his novel [Looking Backward](#) (1888), [envisioned](#) a planned society in the year 2000 in which technology would play a conspicuously [beneficial](#) role. Even such late Victorian literary figures as Lord Tennyson and [Rudyard Kipling](#) acknowledged the fascination of technology in some of their images and rhythms.

Yet even in the midst of this Victorian optimism, a few voices of dissent were heard, such as [Ralph Waldo Emerson](#)'s ominous warning that "Things are in the saddle and ride mankind." For the first time it began to seem as if "things"—the artifacts made by man in his campaign of conquest over nature—might get out of control and come to dominate him. Samuel Butler, in his satirical novel *Erewhon* (1872), drew the radical conclusion that all machines should be consigned to the scrap heap. And others such as William Morris, with his vision of a reversion to a craft society without modern technology, and Henry James, with his disturbing sensations of being overwhelmed in the presence of modern machinery, began to develop a profound [moral critique](#) of the apparent achievements of technologically dominated progress. Even [H.G. Wells](#), despite all the ingenious and prophetic technological gadgetry of his earlier novels, lived to become disillusioned about the progressive character of Western civilization: his last book was titled *Mind at the End of Its Tether* (1945). Another novelist, [Aldous Huxley](#), expressed disenchantment with technology in a forceful manner in *Brave New World* (1932). Huxley pictured a society of the near future in which technology was firmly enthroned, keeping human beings in bodily comfort without knowledge of want or pain, but also without freedom, beauty, or creativity, and robbed at every turn of a unique personal existence. An echo of the same view found [poignant](#) artistic expression in the film *Modern Times* (1936), in which [Charlie Chaplin](#) depicted the depersonalizing effect of the mass-production [assembly line](#). Such images were given special potency by the international political and economic conditions of the 1930s, when the Western world was plunged in the [Great Depression](#) and seemed to have forfeited the chance to remold the world order shattered by World War I. In these conditions, technology suffered by association with the tarnished idea of inevitable progress.

Paradoxically, the escape from a decade of economic depression and the successful defense of Western [democracy](#) in World War II did not bring a return of confident notions about progress and faith in technology. The horrific potentialities of nuclear war were revealed in 1945, and the division of the world into hostile [power](#) blocs prevented any such euphoria and served to stimulate [criticisms](#) of technological [aspirations](#) even more searching than those that have already been mentioned. [J. Robert Oppenheimer](#), who directed the design and assembly of the [atomic bombs](#) at Los Alamos, N.M., later opposed the decision to build the thermonuclear (fusion) bomb and described the accelerating pace of technological change with foreboding:

One thing that is new is the prevalence of newness, the changing scale and scope of change itself, so that the world alters as we walk in it, so that the years of man's life measure not some small growth or rearrangement or moderation of what he learned in childhood, but a great upheaval.

The theme of technological [tyranny](#) over individuality and traditional patterns of life was expressed by [Jacques Ellul](#), of the University of Bordeaux, in his book *The Technological Society* (1964, first published as *La Technique* in 1954). Ellul asserted that technology had become so [pervasive](#) that man now lived in a [milieu](#) of technology rather than of nature. He characterized this new milieu as artificial, [autonomous](#), self-determining, nihilistic (that is, not directed to ends, though proceeding by cause and effect), and, in fact, with means enjoying primacy over ends. Technology, Ellul held, had become so powerful and [ubiquitous](#) that other social phenomena such as politics and economics had become situated in it rather than

influenced by it. The individual, in short, had come to be adapted to the technical milieu rather than the other way round.

While views such as those of Ellul have enjoyed a considerable vogue since World War II—and spawned a remarkable subculture of hippies and others who sought, in a variety of ways, to reject participation in technological society—it is appropriate to make two observations on them. The first is that these views are, in a sense, a luxury enjoyed only by advanced societies, which have benefited from modern technology. Few voices critical of technology can be heard in developing countries that are hungry for the advantages of greater productivity and the rising standards of living that have been seen to [accrue](#) to technological progress in the more fortunate developed countries. Indeed, the antitechnological movement is greeted with complete incomprehension in these parts of the world, so that it is difficult to avoid the conclusion that only when the whole world enjoys the benefits of technology can we expect the subtler dangers of technology to be appreciated, and by then, of course, it may be too late to do anything about them.

The second observation about the spate of technological pessimism in the advanced countries is that it has not managed to slow the pace of technological advance, which seems, if anything, to have accelerated. The gap between the first powered flight and the first human steps on the Moon was only 66 years, and that between the disclosure of the fission of uranium and the detonation of the first atomic bomb was a mere six and a half years. The advance of the information revolution based on the electronic computer has been exceedingly swift, so that, despite the denials of the possibility by elderly and distinguished experts, the sombre spectre of sophisticated computers replicating higher human mental functions and even human individuality should not be [relegated](#) too hurriedly to the classification of science fantasy. The biotechnic stage of technological innovation is still in its infancy, and, if the recent rate of development is [extrapolated](#) forward, many seemingly impossible targets could be achieved in the next century. Not that this will be any consolation to the pessimists, as it only indicates the ineffectiveness to date of attempts to slow down technological progress.

## **The technological dilemma**

Whatever the responses to modern technology, there can be no doubt that it presents contemporary society with a number of immediate problems that take the form of a traditional choice of evils, so that it is appropriate to regard them as [constituting](#) a “technological dilemma.” This is the dilemma between, on the one hand, the overdependence of life in the advanced industrial countries on technology, and, on the other hand, the threat that technology will destroy the [quality of life](#) in modern society and even endanger society itself. Technology thus confronts Western civilization with the need to make a decision, or rather, a series of decisions, about how to use the enormous power available to society constructively rather than destructively. The need to control the development of technology, and so to resolve the dilemma, by regulating its application to creative social objectives, makes it ever more necessary to define these objectives while the problems presented by rapid technological growth can still be solved.

These problems, and the social objectives related to them, may be considered under three broad headings. First is the problem of controlling the application of nuclear technology. Second is the population problem, which is twofold: it seems necessary to find ways of controlling the

dramatic rise in the number of human beings and, at the same time, to provide [food](#) and care for the people already living on the Earth. Third, there is the ecological problem, whereby the products and wastes of technical processes have polluted the environment and disturbed the balance of natural forces of regeneration. When these basic problems have been reviewed, it will be possible, finally, to consider the effect of technology on life in town and countryside, and to determine the sort of judgments about technology and society to which a study of the history of technology leads.

## **Nuclear technology**

The solution to the first problem, that of controlling nuclear technology, is primarily political. At its root is the [anarchy](#) of national self-government, for as long as the world remains divided into a multiplicity of nation-states, or even into power blocs, each committed to the defense of its own [sovereign](#) power to do what it chooses, nuclear weapons merely replace the older weapons by which such nation-states maintained their independence in the past. The availability of a nuclear armoury has emphasized the weaknesses of a world [political system](#) based upon sovereign nation-states. Here, as elsewhere, technology is a [tool](#) that can be used creatively or destructively. But the manner of its use depends entirely on human decisions, and in this matter of nuclear self-control the decisions are those of governments. There are other aspects of the problem of nuclear technology, such as the disposal of radioactive waste and the quest to harness the energy released by fusion, but, although these are important issues in their own right, they are subordinate to the problem of the use of nuclear weapons in warfare.

## **Population explosion**

Assuming that the use of nuclear weapons can be averted, world civilization will have to come to grips with the [population problem](#) in the next few decades if life is to be tolerable on planet Earth in the 21st century. The problem can be tackled in two ways, both drawing on the resources of modern technology.

In the first place, efforts may be made to limit the rate of population increase. Medical technology, which through new drugs and other techniques has provided a powerful impulse to the increase of population, also offers means of controlling this increase through contraceptive devices and through painless sterilization procedures. Again, technology is a tool that is neutral in respect to moral issues about its own use, but it would be [futile](#) to deny that artificial population control is [inhibited](#) by powerful moral constraints and taboos. Some reconciliation of these conflicts is essential, however, if stability in world population is to be satisfactorily achieved. Perhaps the experience of [China](#), already responsible for one-quarter of the world's population, is instructive here: in an attempt to prevent the population growth from exceeding the ability of the country to sustain the existing standards of living, the government imposed a "one-child family" campaign in the 1970s, which is maintained by draconian social controls.

In the second place, even the most optimistic program of population control can hope to achieve only a slight reduction in the rate of increase, so an [alternative](#) approach must be made simultaneously in the shape of an effort to increase the world's production of food. Technology

has much to contribute at this point, both in raising the productivity of existing sources of food supply, by improved techniques of [agriculture](#) and better types of grain and animal stock, and in creating new sources of food, by making the deserts fertile and by systematically farming the riches of the oceans. There is enough work here to keep engineers and food technologists busy for many generations.

## Ecological balance

The third major problem area of modern technological society is that of preserving a healthy environmental balance. Though humans have been damaging the environment for centuries by overcutting trees and farming too intensively and though some protective measures, such as the establishment of national forests and wildlife sanctuaries, were taken decades ago, great increases in population and in the intensity of industrialization are promoting a worldwide ecological crisis. This includes the dangers involved in destruction of the equatorial rainforests, the careless exploitation of minerals by open-mining techniques, and the pollution of the oceans by radioactive waste and of the atmosphere by combustion products. These include oxides of sulfur and nitrogen, which produce [acid rain](#), and [carbon dioxide](#), which may affect the world's climate through the [greenhouse effect](#). It was the danger of [indiscriminate](#) use of pesticides such as DDT after World War II that first alerted opinion in advanced Western countries to the delicate nature of the world's ecological system, presented in a trenchant polemic by American science writer [Rachel Carson](#) in her book *Silent Spring* (1962); this was followed by a spate of warnings about other possibilities of ecological disaster. The great public concern about pollution in the advanced nations is both overdue and welcome. Once more, however, it needs to be said that the fault for this waste-making abuse of technology lies with man himself rather than with the tools he uses. For all his intelligence, man in [communities](#) behaves with a lack of respect for the environment that is both shortsighted and potentially suicidal.

## Technological society

Much of the 19th-century optimism about the progress of technology has dispersed, and an increasing awareness of the technological dilemma confronting the world makes it possible to offer a realistic assessment of the role of technology in shaping society today.

## Interactions between society and technology

In the first place, it can be clearly recognized that the relationship between technology and society is complex. Any technological stimulus can trigger a variety of social responses, depending on such unpredictable variables as differences between human personalities; similarly, no specific social situation can be relied upon to produce a determinable technological response. Any "theory of invention," therefore, must remain extremely tentative, and any notion of a "philosophy" of the history of technology must allow for a wide range of possible interpretations. A major lesson of the history of technology, indeed, is that it has no precise predictive value. It is frequently possible to see in retrospect when one particular [artifact](#) or process had reached [obsolescence](#) while another promised to be a highly successful innovation, but at the time such historical hindsight is not available and the course of events is

indeterminable. In short, the complexity of human society is never capable of resolution into a simple identification of causes and effects driving historical development in one direction rather than another, and any attempt to identify technology as an agent of such a process is unacceptable.

## The putative autonomy of technology

Secondly, the definition of technology as the systematic study of techniques for making and doing things establishes technology as a social phenomenon and thus as one that cannot possess complete [autonomy](#), unaffected by the society in which it exists. It is necessary to make what may seem to be such an obvious statement because so much autonomy has been ascribed to technology, and the element of despair in interpretations like that of Jacques Ellul is derived from an exaggerated view of the power of technology to determine its own course apart from any form of social control. Of course it must be admitted that once a technological development, such as the transition from sail to steam power in ships or the introduction of electricity for domestic [lighting](#), is firmly established, it is difficult to stop it before the process is complete. The assembly of resources and the arousal of expectations both create a certain technological momentum that tends to prevent the process from being arrested or deflected. Nevertheless, the decisions about whether to go ahead with a project or to abandon it are undeniably human, and it is a mistake to represent technology as a monster or a [juggernaut](#) threatening human existence. In itself, technology is neutral and passive: in the phrase of Lynn White, Jr., “Technology opens doors; it does not compel man to enter.” Or, in the words of the traditional [adage](#), it is a poor craftsman who blames his tools, and so, just as it was naive for 19th-century optimists to imagine that technology could bring paradise on Earth, it seems equally simplistic for pessimists today to make technology itself a scapegoat for human shortcomings.

## Technology and education

A third theme to emerge from this review of the history of technology is the growing importance of education. In the early millennia of human existence, a craft was acquired in a lengthy and laborious manner by serving with a master who gradually trained the initiate in the [arcane](#) mysteries of the skill. Such instruction, set in a matrix of oral tradition and practical experience, was frequently more closely related to religious ritual than to the application of rational scientific principles. Thus, the artisan in [ceramics](#) or sword making protected the skill while ensuring that it would be perpetuated. Craft training was institutionalized in Western civilization in the form of apprenticeship, which has survived as a framework for instruction in technical skills.

Increasingly, however, instruction in new techniques requires access both to general theoretical knowledge and to realms of practical experience that, on account of their novelty, were not available through traditional apprenticeship. Thus, the requirement for a significant proportion of academic instruction has become an important feature of most aspects of modern technology.

This accelerated the convergence between science and technology in the 19th and 20th centuries and created a complex system of educational awards representing the level of accomplishment from simple instruction in schools to advanced research in universities. French and German academies led in the provision of such theoretical instruction, while Britain lagged somewhat in the 19th century, owing to its long and highly successful tradition of apprenticeship in

engineering and related skills. But by the 20th century all the advanced industrial countries, including newcomers like Japan, had recognized the crucial role of a theoretical technological education in achieving commercial and industrial competence.

The recognition of the importance of technological education, however, has never been complete in Western civilization, and the continued coexistence of other traditions has caused problems of assimilation and adjustment. The British author [C.P. Snow](#) drew attention to one of the most persistent problems in his perceptive essay [The Two Cultures](#) (1959), in which he identified the [dichotomy](#) between scientists and technologists on the one hand and humanists and artists on the other as one between those who did understand the second law of thermodynamics and those who did not, causing a sharp disjunction of comprehension and sympathy. [Arthur Koestler](#) put the same point in another way by observing that the traditionally humanities-educated Westerner is reluctant to admit that a work of art is beyond comprehension but will cheerfully confess to not understanding how a radio or heating system works. Koestler characterized such a modern individual as an “urban barbarian,” isolated from a technological environment that he or she possesses without understanding. Yet the growing prevalence of “black-box” technology, in which only the rarefied expert is able to understand the enormously complex operations that go on inside the electronic equipment, makes it more and more difficult to avoid becoming such a barbarian. The most helpful development would seem to be not so much seeking to master the expertise of others in our increasingly specialized society as encouraging those [disciplines](#) that provide bridges between the two cultures, and here there is a valuable role for the history of technology.

## The quality of life

A fourth theme, concerned with the quality of life, can be identified in the relationship between technology and society. There can be little doubt that technology has brought a higher [standard of living](#) to people in advanced countries, just as it has enabled a rapidly rising population to subsist in the developing countries. It is the prospect of rising living standards that makes the acquisition of technical competence so attractive to these countries. But however desirable the possession of a comfortable sufficiency of material goods, and the possibility of leisure for recreative purposes, the quality of a full life in any human society has other even more important prerequisites, such as the possession of freedom in a law-abiding [community](#) and of equality before the law. These are the traditional qualities of democratic societies, and it has to be asked whether technology is an asset or a liability in acquiring them. Certainly, highly illiberal regimes have used technological devices to suppress individual freedom and to secure obedience to the state: the nightmare vision of [George Orwell's Nineteen Eighty-four](#) (1949), with its telescreens and sophisticated torture, has provided literary demonstration of this reality, should one be needed. But the fact that high technological competence requires, as has been shown, a high level of educational achievement by a significant proportion of the community holds out the hope that a society that is well educated will not long endure constraints on individual freedom and [initiative](#) that are not self-justifying. In other words, the high degree of correlation between technological success and educational accomplishment suggests a fundamental democratic bias about modern technology. It may take time to become effective, but, given sufficient time without a major political or social disruption and a consequent resurgence of national

assertiveness and human selfishness, there are sound reasons for hoping that technology will bring the people of the world into a closer and more creative community.

Such, at least, must be the hope of anybody who takes a long view of the history of technology as one of the most formative and persistently creative themes in the development of humankind from the Paleolithic cave dwellers of antiquity to the dawn of the space age. Above all other perceptions of technology, the [threshold](#) of space exploration on which humankind stands provides the most [dynamic](#) and hopeful portent of human potentialities. Even while the threat of technological self-destruction remains ominous and the problems of population control and ecological imbalance cry out for satisfactory solutions, man has found a clue of his own future in terms of a quest to explore and colonize the depths of an infinitely fascinating universe. As yet, only a few visionaries have appreciated the richness of this possibility, and their projections are too easily dismissed as nothing more than imaginative science fiction. But in the long run, if there is to be a long run for our uniquely technological but willful species, the future depends upon the ability to acquire such a cosmic perspective, so it is important to recognize this now and to begin the [arduous](#) mental and physical preparations accordingly. The words of [Arthur C. Clarke](#), one of the most perceptive of contemporary seers, in his *Profiles of the Future* (1962), are worth recalling in this [context](#). Thinking ahead to the countless aeons that could stem from the remarkable human achievement summarized in the history of technology, he surmised that the all-knowing beings who may evolve from these humble beginnings may still regard our own era with wistfulness: “But for all that, they may envy us, basking in the bright afterglow of Creation; for we knew the Universe when it was young.”