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Changing Attitudes to Science: From Pro-Science to Anti-Science – and Back?

Ever since the beginning of the modern period almost five centuries ago we have contrasting attitudes toward science. On the one hand there is a fascination with knowledge and the power over nature. On the other hand, there is a rejection of science based either on a presupposed inability of science to find the truth, or, conversely, on a fear of science being too efficient. If we focus on the period after World War II, we can easily identify these alternative attitudes toward science. (For a discussion of earlier periods of proscience and antiscience, see e.g., Holton, 1993).

The optimism after World War II led Vannevar Bush to proclaim science as "the endless frontier," which would lead humanity to progress and prosperity (Bush, 1945). About a decade later, in 1956 in the former Soviet Union, science was declared "a direct productive force." (In fact, hardly any other country has put so much hope to science as the former U.S.S.R.). But at the same time the Cold War was gaining speed, involving many scientists in weapon making. This created a reaction against science: the critics feared that science and the technology it produced might slip out of human control and endanger the very existence of the human race (e.g., Kevles, 1987, chapter 16).

Positive or negative, both attitudes were based on the same belief in the omnipotence of science. However, by the 1970s a new form of critique of science emerged, this time in the form of philosophical relativism and social constructivism. Unlike the earlier critics, the new critics challenged the very foundations of science: its ability to find truth and solve problems. This critique gained momentum and reached a peak in the postmodernist era of the 1980s. To many scientists and to philosophers and sociologists trained a generation earlier, this seemed as a wave of obscurantism and a real antiscience movement. In the light of these recent developments, it is interesting to ask the question: What produces certain attitudes to science, either for or against?

We can get some guidance by examining cases of proscience or antiscience sentiments and movements in their historical context. For instance, the famous slogan of

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Vannevar Bush, "science the endless frontier," can be linked to a period in the history of the United States, which historians of technology have characterized as a period of "technological optimism." Generally speaking, this is the time between 1870 and 1970, as depicted by the historian Thomas Parke Hughes in his book American Genesis (Hughes, 1989). However, while the spirit of this century in American history may be uniformly regarded as one of technological optimism, historically speaking it is rather complex. Periods of economic growth interchanged with stagnation, the country moved through modernization, urbanization and demographic transition, and the nation participated in two World Wars. This is also reflected in the shifting attitudes to science during this time.

Vannevar Bush's famous manifesto was published in 1945, but it rather marks a process which began much earlier. The immediate precursor of the developments in the postwar period was the period between the two World Wars, and it is in fact this time that is the best example of high beliefs in science and its ability to solve social problems. While science could not avert the Great Depression, during that era there was a proliferation of projects for bringing the country to prosperity by the means of scientific discovery. Indeed, during the worst times of the Depression in 1933 and 1934, the famous exposition Century of Progress was organized in Chicago. There, in a most direct way millions of people were introduced to technological marvels, which promised to change human existence (Rydell, 1993). All this bright future was to come about through the application of science to the economy and everyday life.

Scientific fairs have a long history since, starting with the English Crystal Palace exhibit of 1851. In the 1930s, however, they acquired a special meaning throughout the industrialized world: they were to assure the million victims of the Great Depression that the bad times would be overcome by the magic of science. During the same time, the Soviet Union was experiencing a comparable social and economic crisis: the pains of rapid industrialization. Also there, science exhibits flourished. A testimony to the faith in science in the Soviet Union was that one scientific exposition in Moscow was made permanent and lasted till the end of the Soviet Union.

But it was not really science that rescued these countries from their economic problems. The real restructuring of the economy occurred in fact during World War II through the enormous efforts of the fighting nations. This war also saw the implementation of a major discovery made in a very abstract scientific field: atomic physics. Indeed, until the mid-30s atomic physics was considered too theoretical and remote from practical applications even by some famous scientists, like Rutherford. In the Soviet Union, scientists were simply forbidden to work in atomic physics and ordered to go into more practical research instead. However, by the beginning of World War II, all of a sudden new discoveries made atomic physics a hot field, resulting in the atom bomb in 1945.

It is a good question to ask whether it was this unexpected outcome from an abstract area of science that made Vannevar Bush insist that pure science should have pre-eminence over applied research. Anyway, this was to become the paradigm of science policy throughout the next 50 years. It is only recently that the wisdom of Bush's pure science idea has come to be challenged. For instance, a recent article in *Science* called "The changing ecology of United States' science" appealed for a return to the interwar concept of "useful knowledge" instead of "pure science" as a guideline for science policy (Byerly and Pielke, 1995).

The "useful knowledge" approach was something that flourished particularly in the former Soviet Union. It was exactly by promising useful knowledge that the old Imperial Academy of Sciences in St. Petersburg was able to successfully transform itself into the new Soviet Academy of Sciences in Moscow. Through this manoeuvre, this remarkable scientific body managed to regain state patronage and retained considerable autonomy in spite of the zig zags of ideology (Vucinich, 1984). In the post-war period the concept of preeminence of basic research gained some currency in the rhetoric of the Soviet Union. Still, science continued being considered a "direct productive force". This became the official doctrine in 1956.

Enthusiastic belief in science had existed in other nations before, but hardly on such a scale as in the Soviet Union. Science was believed to be the key to economic success in truly Baconian fashion. Popular science journals published in millions of copies every month provided a beautiful world picture, just as Tomaso Campanella might have wished it. Indeed, the reliance on science was so strong that scholars from various fields even developed the special discipline of 'science of science', which was supposed not only to study science, but also to steer it scientifically.

The science of science movement started in 1959 in Prague, where the 20th anniversary of John Desmond Bernal's book *The Social Function of Science*, was celebrated. While the slavic term for 'science of science' actually originated in Poland in the 1930s and etymologically resembles the term 'Wissenschaftslehre' coined by Bernard Bolzano in the 1830s, the Bernalian connection marks the new use of this concept. John Bernal was part of the group of leftist British scientists in the 1930s, whom Gary Werskey named "The Visible College" (Werskey, 1978). Indeed, many of them participated directly in politics and advocated a socially responsible science.

Bernal's book, which is as structured as a treatise on crystallography might be, ends with a paragraph "Science as Communism" (Bernal, 1964). While it could be argued that there was some Soviet connection with this British development, actually the influence might have come from France. Indeed, the famous essay of Boris Hessen at the History of Science congress in England in 1931 made a connection between historical formations and the internal development of science (Hessen, 1931). Visitors to the Soviet Union, like Julian Huxley in 1930, wrote sympathetic accounts of Soviet science and the prospects it opened for the economy (Huxley, 1932). According to Terry Shinn, however, it was the French leftist program for science buildup of the 1920s which influenced Bernal and the other British scientists. The French scientists wanted the establishment of a special structure amounting to nothing less that a state within the state (Shinn, 1994). After 1936, when a left-wing government came to power in France, this project became viable, and indeed, the Centre National de la Recherche Scientific (CNRS) was established in 1939. The institution resumed work in 1945. Actually, this became the model of scientific organization for the Comecon countries to follow from the 1960s to the 1980s.

The term 'science of science' had some currency as well in other countries, although in the West it was mostly believed that prosperity through science would come about by more democratic means and just by sponsoring science and developing it along Western academic traditions. A volume from 1964 on this topic (Goldsmith and MacKay, 1964) contains a cautious assessment of science of science by Derek Price (Price, 1964) along with chapters discussing how Third World countries would achieve modernization and prosperity if they only developed their national science.

So far, I have focused on two famous slogans from the post-war era: "science the endless frontier," and "science as a direct productive force." But the number of examples could be expanded. One such case is the development of chemurgy in the interwar period in the United States. The name translates as "action by the means of chemistry." It was a program for scientific and sociopolitical development aiming to take out American agriculture from depression and to boost the economy into a new era of growth and expansion. This case is interesting because of the fact that it was not linked to the state bureaucracies or the military-industrial complex. Indeed, among the sponsors of chemurgy were self-made men and famous capitalists such as Henry Ford.

Chemurgy emerged as a research program in the late 1920s, when American agriculture began to suffer from overproduction. This brought about ideas to use farm products as raw material for the chemical industry. According to the authors of these projects, scientific research and technological development could create new industries, which could absorb agrarian surplus and make the farmers prosperous. The prosperous farmers, then, would start spending on industrial goods, which, in turn, would stimulate industry. Thus, in the end, economic growth and prosperity could be achieved by the implementation of science (Borth, 1939). This program enjoyed enormous popularity in the 1930s, when 25% of the American population were farmers and millions of people suffered unemployment because of the Depression. As such, also this program can be interpreted within the earlier mentioned concept of "useful knowledge."

Actually, chemurgy did not fulfil its promise – perhaps for reasons lying outside science. But there was another scientific program, which turned out to be quite efficient – German chemistry. Throughout the first third of this century, Germany developed technologies to synthesize materials needed by its economy in peace and war. This enabled the country to survive the era of imperialism and two world wars and gave rise to the German expression: "chemistry – the land of opportunity." The phrase was coined by Emil Fischer in 1911 at a meeting attended by the Kaiser in 1911 (Johnson, 1990). "The land of opportunity" was actually a paraphrase of the thesis about the "endless frontier," a vision of American history which gained popularity in the 1890s with Frederick Jackson Turner. Thus, the German concept in fact predates the slogan of Vannevar Bush with more than 30 years. It is not surprising that for Germany, which did not have a large territory like the United States or Russia or a colonial empire like Britain or France, science would be seen as the means to economic progress.

There is long tradition in German science of chemistry being tied to national interests. This tradition begins with Glauber in the 17th century and continues with Liebig in the mid-19th century, and with Haber, Bosch, Bergius and others in the early twentieth century. Liebig appealed to German chemistry to be socially responsible – he called the chemistry of his days "asocial." While Glauber and Liebig can be linked to the study of fertilizers and the improvement of the productivity of German agriculture, others developed synthetic chemistry, which made Germany almost self-sufficient.

Thus Germany, a latecomer in the industrial world, sought to compensate for the lack of colonies and natural resources by fostering chemical synthesis. The impact of some of these scientific developments was of a global nature. By the end of the 19th century, Adolf von Baeyer was able to synthesize indigo, which led to the collapse of the British indigo plantations in India (Bud, 1994). The synthetic dye industry had emerged with Perkin in England but was brought to a high art in Germany. This success, in turn, brought about attempts to solve other problems with raw materials of prime importance. The Haber-Bosch process of nitrate synthesis eliminated Germany's dependence on imports from Chile and provided ammunition for World War I. The most famous cases are the ammonia synthesis developed by Haber and Bosch, and the synthesis of gasoline from coal developed by Bergius. All of these scientists received Nobel prizes, thus testifying to Alfred Nobel's own vision of useful knowledge (Cholakov, 1986).

Remarkably, Bergius even managed to produce sugar from wood. (As a demonstration, he was giving candy made of hydrolyzed wood to visitors from his laboratory; Robert Bud, personal communication). In 1939, Bergius' success caused an American journalist to snappily remark that now, in a case of war, Germany could eat its forests! (Borth, 1939). Indeed, Bergius' efforts were seen as a national achievement. A biography of Friedrich

Bergius published in Berlin in 1943 has the title: "Ein Deutscher Erfinder kämpft gegen die Englishe Blokade" (Schmidt-Pauli, 1943). It has two parts: I. Kraftstoff aus Kohl, and II. Nahrung aus Holz.

The late 19th century, labelled by its contemporaries as an age of imperialism, saw a divided earth and a struggle for resources. In such restrained conditions, it is little wonder that different nations put their hopes to science and perceived it as alternatively the land of opportunity, the endless frontier or a direct productive force. The time between the mid-19th and the mid-20th centuries saw rapid modernization and industrialization, first in Europe and then in other parts of the world. Change became part of the everyday experience for millions of people and the claim of scientists that it was science that had brought about the change found a ready audience among both masses and elites. Meanwhile, in some cases the scientific establishments did provide crucial support to their nations, for example in England and Germany during World War I and the United States during World War II.

But just as, historically, technological optimism was produced by modernization, the pains of industrialization generated antiscience sentiments. A famous early example is Mary Shelley's *Frankenstein* from 1818; a later one is Jacques Ellul's writings about the power of technology over man in 1954, a book that was translated into English only in 1964 (Ellul, 1964). These antiscience views and fear of technology typically reflect a fear of change and a nostalgy for the rural past. Present-day environmentalism is one of the offsprings of these sentiments.

The beginning of the Great Depression in 1929 brought doubts about the beneficialness of science. By 1930 there were calls in Britain and the United States for a moratorium on further research in science and mechanization in industry (Mendelsohn, 1994). These fears would resurge again in the 1960s, when automation seemed imminent and are still perpetuated by writers like Edward Luttwak, who believes that the danger of automation was only postponed (Luttwak, 1994).

In the period after World War II, there was another line in antiscientism, indirectly engendered by the Manhattan project. Big science came increasingly to be regarded as big power. Some of the social scientists in the 1970s and '80s came to see themselves as fighters against powerful establishments entrenched in science and politics. By showing the shortcomings of science, they believed that they could undermine the claims and legitimacy of those very establishments. This made sense during the times of the Cold War, when to many the world seemed to be on the brink.

This brings us to one of the uses of science which is not much talked about. This is the link between science and the military. Of course, this connection can be brought back to Archimedes, if necessary. Renaissance figures like Leonardo da Vinci and Galileo can be mentioned. In search of favors and patronage scientists offered to princes not only gold-making but also better weaponry. The French state incorporated science together with engineering with the military, and so did the Russian empire. In liberal 19th century France, however, powder-making was left predominantly to individuals like Alfred Nobel, who was not even a national (Cholakov, 1986).

All this changed with World War I, during which science played an important role in the war effort either through German chemistry (nitrate explosives), British microbiology (rubber made by the Weizmann method) or French medicine (preventing epidemics among soldiers). Probably only in Russia did this effort to continue research for the aims of national security persist without interruption. World War II again mobilized scientists for state and military service. This time there was an unexpected discovery: atomic fission, which led to the creation of terrifying weapons and an arms race.

It is useful here to take one more look at *Science the Endless Frontier*. Vannevar Bush himself was one of the architects of the mobilization of American science for the military effort. When he in his manifesto reiterated the promises of science in solving the problems of society, he had also something else in mind than the abstract notion of useful knowledge. He wanted to preserve the scientific establishment which had emerged during the war.

In American history it is traditional to have a post-war slump and depression. This is also what happened in the mid-1940s. However, by the end of the decade the Cold War and the Korean War mobilized the nation once again – indeed, as Dean Acheson famously put it, "The Korean War saved us" (Yergin, 1977). Such was the buildup throughout the 1950s that in 1959 President Eisenhower spoke with concern about the power of the military-industrial complex.

After the war, however, Vannevar Bush had chosen to speak for the preeminence of pure research over applied research and argue for pure research as the road to useful knowledge. Indeed, for several decades the scientists built larger and larger accelerators, larger and larger telescopes, explored the oceans and sent men and probes in outer space. While this was perceived with great enthusiasm by the people of the United States, the Soviet Union and other nations, eventually a point of saturation was achieved. Now that the Cold War is over, many of these areas of research are shrinking. In 1989 the Berlin wall, the very symbol of the Cold War, was torn down. Some time after that far away in Texas, the greatest project of post-war science, the superconducting supercollider ran into trouble, and was eventually dismantled. To many scientists, the end of the SSC signified a changed attitude to science in society. Nobel prize winners like Leon Lederman spoke about "the end of the frontier" (Lederman, 1991).

However, this leaves those who witnessed the post-World War II developments with the question: Did the accelerators in fact model nuclear reactions in exploding bombs? Did the big telescopes watch for enemy satellites? Did the oceanographers scout for somebody else's submarines, or did the landing on the Moon symbolize the success of rocketry? These questions certainly are getting coverage in recent scholarship and the Faustian bargain between pure science and military research may become more explicit (Leslie, 1992, 1993). In this connection the attack on science during the post-modernist 1980s may be perceived as an attack on power , quite in the spirit of the leftist and radical tradition. Indeed, in the time of Star Wars, science was so much identified with power that some academics may have believed that they could change the world through political activism within science – or by devoting themselves to science studies.

Meanwhile, if Big science was indeed primarily linked to military projects and the end of the Cold War removed some of this type of science from the nation's top priority list, then one might argue that recent anti-science sentiments generated by social scientists and environmentalists may in fact have been skilfully exploited by politicians to cut down the science budget (In 1987, the physicists Theocharis and Psimopoulos made this type of argument for science in Britain; for more detail, see Segerstråle's article in this issue).

Now the Cold War is over, the budgets for research are cut throughout the world, and we are all somewhat bored with science. Now what? The exponential growth of Big Science, as observed by Derek Price in the early 1960s (Price, 1963), has come to an end – a situation which John Ziman describes as "science in a steady state" (Ziman, 1994). But the case is not only that pure and applied research are more and more fused, as are also the boundaries between science departments and corporate structures. Today's scientist may turn out to be also a venture capitalist, a patent holder, a developer, and a salesman. Science has become a sort of high-tech craftsmanship.

While this may seem as an end of an era to some, one could argue that this steady-state science is actually a return to the early modern condition and the Baconian program. Science is finally becoming a direct productive force. The artificial bubble of the Cold War era is gone, but that will only put science to solve more of the real problems of the world. If we draw a historical parallel, today's receding enthusiasm about science is similar to 18th century England, where science turned into a technicality during the Industrial Revolution. In this respect the grand science of the recent past will look similar to the state-sponsored and militarized science of the Ancien Regime which failed to reform itself and fell victim to a revolution. We probably have little to regret about it and everything to hope for.

Still, this is probably not the whole story. Indeed, the supercollider was abandoned, but meanwhile the United States government invested in the Human Genome Project. This project so far has not produced much of importance for science, but may be regarded as an investment in the future. This shows that science continues to be considered of strategic importance by the governments in the United States and Japan, and by the European Union. But the public seems unimpressed. With particle physics in the doldrums and genetic engineering at a standstill, the question is: Can we expect once again a period of change and discovery which will boost the popular belief in science, and which might affect academic sentiments about science in the same way? Or, to put it in other words, what might be the equivalent of splitting the atom or the discovery of DNA, which would once again shift opinions in favor of science and its promise?

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