Science, Technology and Democracy: Distinctions and Connections

Prologue: The Cold Fusion Fiasco

On March 23, 1989 Martin Fleischman and Stanley Pons appeared at a press conference at the University of Utah where they announced the discovery of cold fusion. The President of the university and several other officials were also present and spoke to the press. The unaccustomed involvement of the press and these officials signalled that cold fusion was more than a scientific advance. Soon the University announced the formation of a research institute with funding from the state. Its goal was not only to produce knowledge of the phenomenon but also to prepare large scale commercial applications. It seemed possible at first that cold fusion would revolutionize electricity production and transform the world economy.

We know the end of the story. Within a short time cold fusion was discredited and most researchers lost interest in it. The institute at the University of Utah closed in 1991 and support for further work in this field quickly evaporated.[1] These events provide a particularly clear illustration of the complexity of the relation between science and technology today.

The classic but generally discredited account of these relationships holds that science is a body of truths about nature and technology an application of these truths in the production of useful devices. Truth and utility belong to different worlds linked only by the subordination of the latter to the former. But historians have shown that few technologies arose as applications of science until quite recently. Most were developed independent of science and, indeed, in cases such as optics had more impact on science than vice versa. Science is even more dependent on technology today than in the past. It is true that the 20th century saw a dramatic increase in practical applications of scientific knowledge, but this new situation does not reveal the essence of the science-technology relationship. Rather, it confounds the common sense distinction by establishing the productive character of science itself.

In any case, the classic model does not describe cold fusion. Fleischman and Pons did not apply any existing science in their work but made an empirical discovery of the sort that we associate with invention. They were not seeking to confirm or invalidate a theory with experiment as philosophical accounts of scientific method would have it, but rather aimed to produce an unexplained (and ultimately unexplainable) effect. Their discovery employed a technical device that was both an experimental apparatus and a commercial prototype. Accordingly, the two pronged launch of their discovery at a new conference aimed at both the scientific and the business communities.

Cases such as this one proliferate in the biological sciences, where scientific techniques are deployed in the search for results of interest not only to researchers but also to pharmaceutical houses. Products and knowledge emerge from the laboratory together. The pursuit of knowledge and the making of money are joined in a single labor. The distinction between science and technology appears to break down. Hence the widespread use of the term “technoscience.”

Distinguishing Science and Technology

Postmodern scholars and many researchers in Science and Technology Studies no longer believe there is any distinction of principle between science and technology. This scepticism about the traditional distinction confirms the worst prejudices of some leftists who blame science and technology for the mess the world is in today. Certainly the boundaries between science and technology are much fuzzier than in the past and science is thus implicated in the failures of technology to an unprecedented extent. But if we conclude that they are no longer distinguishable at all, what becomes of the associated distinctions

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[1] Simon, Bart (2002). *Undead Science: Science Studies and the Afterlife of Cold Fusion.* New Brunswick: Rutgers University Press.

between theory and practice, research and application, scholarship and business, truth and utility? Must they be given up too?

The old distinction between science and technology and all these associated distinctions implied a value hierarchy. Science, theory, research, scholarship and truth were considered nobler than technology, practice, application, business and utility, in accordance with the ancient preference for disinterested contemplation over worldly activity. This hierarchy grounded the demand for the complete autonomy of science. In 1948 P.W. Bridgman expressed this "ivory tower" indifference when he said "The assumption of the right of society to impose a responsibility on the scientist which he does not desire obviously involves the acceptance of the right of the stupid to exploit the bright."[2]

As the distinction between science and technology blurs, the value hierarchy that justified such outrageous snobbery loses its persuasive force. A basic change has occurred in the relationship between science and society. There is growing openness on the part of science to various forms of political and economic control and in some cases what I will call "democratic intervention" by lay members of the public. But what exactly do we mean by this?

Certainly not eliminating the laboratory, obliging scientists to work with the public looking over their shoulders, and relying on government for epistemic decisions. Democratization and political and economic intervention into science are more modest in their objectives for many reasons. But public action regarding technology is considerably more ambitious. It occurs more and more frequently and it often leads to direct intervention by citizens and governments into technological decisions and even into the decision-making criteria employed to select technologies.

The old value hierarchy has been scrambled in recent years as more and more scientific work aims directly at producing marketable goods. We live in a two dimensional flatland, not a three dimensional universe with vertical coordinates. But despite the changes, we cannot do without the old distinctions. They correspond to vital strategic divisions within the world of politics. The question is, how can we reconstruct the distinction between science and technology without falling back into an outmoded valuative framework? That is what I will attempt here.

In the remainder of this presentation I want to offer a new framework for discussing the relationship between science, technology and democracy. I will discuss four issues. First, I want to introduce some basic criteria for making the distinction that concerns us here. Second, I will propose a sketch of the evolving cognitive relation of science and society in recent years. Third, I will argue that democratization has a specific significance for technology it does not have for science. In conclusion I will place the issues raised in this lecture in a wide historical context.

Two Criteria

Even if it is sometimes difficult to distinguish the pursuit of truth from the pursuit of utility, other criteria enable us to the make a usable distinction between science, technology and technoscience. I am not concerned here with the obvious cases such as the difference between theoretical physics and road work. The difficult cases are more interesting. They arise in the expanding zone of activities that appear to cross the line between science and technology. Engineering has always occupied that zone at the cognitive level, but in practical terms it usually contributed to technical projects. Today the projects themselves have lost clear definition. Criteria for distinguishing science and technology can still be developed from study of scientific and technological practice, for example, the subtle differences in the roles of knowledge and technique in experimental research and science based technology.[3] Here I will focus on criteria reflecting significant differences in governance and procedures because they are directly relevant to the politics of science and technology.

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[2] Bridgman, P.W. (1948). "Scientists and Social Responsibility," in *Bulletin of the Atomic Scientists,* vol. 4, no. 3, p. 70.

[3] Radder, Hans (2009). *Handbook Philosophy of Technology and Engineering Sciences*, ed. A. Meijers,. Amsterdam: Elsevier, pp. 71-87.

Since the 17th century, the study of nature has been organized by scientific societies and communities, at first informally, and later formally and officially through academic credentialing and employment. This relative cohesion and autonomy of the scientific community persists even today despite all the intrusions of business, government, and the public. Scientific controversies are decided by the scientific community, or rather, by what sociologists of science designate as a "core set" of researchers engaged in debating the relevant scientific issues. Social, cultural and economic constraints play only indirect roles in these debates, for example, empowering some participants to carry out expensive experiments or influencing the initial response to the announcement of results. But in the final analysis epistemic tests carried out by individuals or small groups in conferences, articles, and laboratories are the principal measure of competing ideas.

I do not mean to imply that scientists' ideas are free of social influences, but they do often achieve credible knowledge of nature and this is their primary aim, the make-or-break factor in their work, even if that work also involves them in commercial activity. This conclusion need not imply a positivistic understanding of science. For the purpose of the argument here, one can consider the epistemic labors of scientists as highly skilled crafts rather than as the pursuit of a transcendent truth.

Technology too involves knowledge of nature but many of the most important decisions in this case are not about knowledge. A quite different history has shaped the domain of useful invention and production. Technology has always been far more closely integrated to society than science, either through institutions such as guilds or through direct employment in industry.

Social and economic criteria are relevant to technological choices and intervene through the mediation of organizations such as corporations or government agencies that employ technical workers. These workers, who may be scientists, are usually situated in a chain of administrative command leading up to individuals in non-technical roles with wide responsibilities that have nothing to do with knowledge of nature. Where those individuals determine outcomes, we can be fairly certain we are dealing with a primarily technical activity, even if scientific knowledge is ultimately generated as a by-product.

Of course the boundaries are fuzzy, as scholars in science and technology studies insist. It is easy to cite examples that are difficult to classify. Technical workers, until recently of lower class background and poorly educated, have always possessed considerable knowledge of nature. Galileo's dialogue on *Two New Sciences* begins with a reference to "conferring" with the wise craftsmen of the Arsenal, as though with intellectual equals.

The science/technology distinction is often associated with the distinction between academic and corporate-military research. But there are obvious counter-instances such as Bell Labs where high quality scientific world has been done under corporate auspices. Nevertheless, there is a difference between the kind of research done in universities and Bell Labs and most product development, including development that employs laboratory methods but which is conducted in secret or used to promote specific products.

The institutional separation of mainstream science and technology, consecrated in the 19th century in the academic status of the most important researchers while engineering became a staff position, has developed continuously from one generation to the next for centuries. This suggests a first criterion for distinguishing science and technology: the difference in decision procedures in the two cases.

Current technoscience does not represent the erasure of the difference, but only its latest stage. The cold fusion affair illustrates this stage, in which science and technology are practiced simultaneously. The pursuit of commercial cold fusion depended on the willingness of the state of Utah to invest in a likely money-maker. The research was to be oriented toward this goal. Within the institute the existence of cold fusion was not in question and the experiments were conducted in secret. But the very same effect which the organization was created to exploit was also exposed to scientific evaluation and this proved to be decisive. There the potential profits to be made on commercial electricity production were attention-getting but less significant. Scientific criteria were brought to bear on the effect, so far as knowledge of its production was available, and it was rapidly discredited, primarily by two epistemically significant factors: failures to reproduce the effect in the laboratory, and lack of a plausible connection between the effect and existing theory. Clearly, truth and utility still belong to distinguishable worlds, even if they refer to aspects of one and the same phenomenon and often cross boundaries in pursuit of their separate goals. The point of intersection, where scientific and technological criteria must both be aligned, corresponds to successful technoscience.

A second related criterion useful for distinguishing science and technology is the different role of underdetermination in the two cases. The concept of underdetermination was introduced by the French historian Pierre Duhem to explain the fact that scientific theories are not uniquely determined by observation and experiment. The interpretation of these tests of theory always depends on other theories and so the whole edifice of knowledge is implicated in the evaluation of any particular branch of it. In practice, this means that no logically decisive experiment can relieve the researcher of the need to make a personal decision about the truth or falsity of the tested theory. Such decisions, Duhem claimed, are based on "good sense." They are rational, or perhaps "reasonable" is the better term, but not possessed of the certainty often claimed for science.

Cold fusion illustrates this conclusion, if not Duhem's precise point, since failures to reproduce the effect were interpreted by Pons and Fleischman as technical breakdowns and by their opponents as proving the non-existence of the effect. The decision between these two interpretations could not be made on the basis of experiment alone since the competence of the experimenters was in question.

Variations on this theme have been discussed in philosophy of science for a century. No doubt there is something to it. But Pons and Fleischman discovered that ad hoc explanations are weak defences for anomalous and conflicting experimental results such as characterized the cold fusion case. The only effective move in such cases is the production of new theory that encompasses old and new observations alike. But the production of plausible scientific alternatives is extraordinarily difficult. Advocates of cold fusion were unable to supply one. Their failure is not unusual. Although Einstein objected to the uncertainty principle, he found it impossible to come up with something better. Creating new scientific theory requires rare originality and a special kind of critical insight into existing theory.

The case with technology is quite different once again, not least because alternatives are usually easy to invent. The concept of underdetermination can be adapted to signify this difference. It is obvious to engineers and other technical workers that no "technological determinism" or "technological rationality" dictates a single design of each device. The technical equivalent of Duhem's "underdetermination" of scientific observation and experiment is the proliferation of alternative designs of roughly similar devices. Just as observation and experiment can have different meanings in different theoretical contexts, so devices can be designed differently and have different meanings in the larger framework of the society.

There are of course hard technical problems such as the AIDS vaccine. We will be lucky to find a single successful design, much less a multiplicity among which to choose. But most technical problems are not so hard and alternatives are available. The question then is how choices are made among them. Technical underdetermination leaves a wide opening for social, cultural and economic criteria to weigh on the final decision between alternatives. The equivalent of scientists' "good sense" in this case is supplied by management sending orders down the chain of command to technical workers whose advice they may or may not have taken into consideration. This high degree of flexibility is what makes the management of technology development possible with a degree of top down control that is very unusual for science.

Again, technoscience is a special case in which characteristics of both science and technology are mixed. Aspects of technoscientific work share the very limited scope for alternatives typical of science, while other aspects compensate with a wide range of technical possibilities. The development of pharmaceuticals is a good example. A great deal of scientific knowledge is involved, and this is organized in an at least provisionally authoritative corpus. Management does not pick and choose among the items in this corpus but relies on scientists to identify the useful bits. At the same time, experimental substances abound and research laboratories have developed procedures for rapidly mining the possibilities for worthy candidates for study. The study of these candidates is arduous and expensive and often leads to ambiguous results. Managers and government agencies are deeply involved with the selection of research projects and the approval of new drugs.

The blurring of the boundaries between science and technology has brought huge sums of private money into research with many useful outcomes. But it has also had an unfortunate influence on the evolution of research funding. In recent years neo-liberal ideologists have convinced governments that the responsiveness of science to society is measured by the commercial success of its applications. Such a tight bond between business interests and research funding is not always desirable. Publication and public support for basic research in a wide variety of fields, including many with no immediate prospect of commercial payoffs, are the basis of long term scientific advance. Practices of secrecy, deception and tight control over employee speech that are commonplace in the business world distort research and damage careers. It is also essential that science have the means to serve the public interest even where business prospects are poor, as in the case of medicines for "orphan" diseases. This new system reduces science to a handmaiden of technology, with unfortunate consequences because not all of science is "techno-" and not all "techno-" is profitable.

Democratizing Science

With these distinctions in mind, I want to introduce some historical considerations on the concept of the democratization of science. Science was always marginal to national politics until the Second World War. The Manhattan Project and radar research actually changed the course of the War and thereafter the union of science, government, and eventually business became one of the driving forces of social and economic development. Science was exposed to new forms of public intervention as a result. I will sketch this history very briefly in the American context.

The Manhattan Project played a special role in this transformation of the relationship between science and society. The scientists involved were sworn to secrecy throughout the War. They acted as agents of the federal government under military command. But they realized toward the end, when it came time to decide whether or not to use the bomb, that they were not simply government employees. Because of the secrecy of the project, they were also the only citizens able to understand the issues and express an opinion.

Under the leadership of Leo Szilard and James Frank they attempted to enact their role as citizens by petitions and reports advocating non-use. They were unsuccessful but after the War, when they were no longer bound by military secrecy to the same degree, a number of them committed themselves to informing public opinion. The famous *Bulletin of the Atomic Scientists* was the semi-official organ of this "scientists' movement." It had wide influence but it took many years for its advocacy of test bans and disarmament treaties to have an effect on public policy.

There was a strong element of technocratic paternalism in this movement. In the immediate post-War period, up until the middle 1960s, technocratic notions were widely believed to chart the course for the future of modern societies. Politics was increasingly guided by technical experts of one sort or another. But the problem of what to do about public opinion remained once its input was devalued relative to expert advice. One solution consisted in refining the techniques of persuasion. Scientists chose a more respectful alternative and attempted to educate the public. Their efforts were motivated by the sense that an uninformed public might obstruct essential government decisions based on scientific knowledge.

This experience influenced the attitude of scientists in the 1960s and '70s as the environmental movement began to take shape. Biologists saw themselves in the role of the atomic scientists of the post-War period, possessed of knowledge of critical importance to the public. They too attempted to inform the public, advocating science-based solutions to problems most people could barely understand.

But technocratic paternalism soon gave way to a new pattern. Disagreements arose among environmentalists in the early 1970s and weakened the authority of science. True, some physicists disagreed over issues such as civil defense but the vast majority of the articulate scientific community favored the policies embodied in the treaties that still falteringly regulate nuclear affairs. No such consensus emerged in the environmental movement. In fact there were open conflicts over the causes of pollution, some blaming over-population and others blaming faulty technology, some calling for more vigorous regulation of industry, others for a return to nature or at least to "voluntary simplicity."[4]

The appearance of politically significant splits in the environmental movement meant scientists could no longer occupy the role of teacher to an ignorant public, but that they were obliged instead to play politics in the search for public support. For a population that made little distinction between science and technology, the loss of authority that resulted from these controversies was amplified by a series of technological disasters. The Vietnam debacle testified to the limits of the kinds of knowledge and power the technocratic state had at its disposal. The Three Mile Island nuclear accident in 1979 refuted the standard measures of risk put forward with such misplaced confidence by the scientific and engineering community. The Challenger accident in 1986 was a rebuke to the hubris of a nation that was proud of having put a man on the Moon. Many other incidents contributed to a gradual shift in sentiment and by the end of the millennium few young people were choosing scientific careers and strong fundamentalist movements were increasingly effective in opposing the teaching of science in schools.

Against this background a new configuration gradually emerged. By the 1970s we were beginning to see more public awareness of medical and environmental issues that affected individuals directly in their everyday experience. These issues were not confined to the realm of public discourse as had been nuclear issues in an earlier period. Now individuals found themselves involved in scientific-technical controversies as victims or potential victims of risky technical activities. In cases such as these ordinary people sometimes possess part of the truth before scientists interest themselves in their problems. That is a reason for scientists to listen as well as speak, to accept the role of learners as well as the role of teachers. In this context small groups of scientists, technologists and citizens began to explore an entirely new relationship between science and society. This relationship took the form not of paternalistic education but of a true collaboration with community activists.

A signal instance was the Love Canal struggle in the late 1970s. Residents of this community organized to demand government help dealing with the nearby toxic waste site that was sickening them and their children. They worked closely with volunteer scientists to document the extent of the problem and eventually won reparations. In this case lay informants brought a problematic situation to the awareness of scientists and collected useful epidemiological data for them to analyze.

Another similar movement among AIDS activists in the 1980s started out with considerable conflict and distrust between patients and the scientific-medical community. Patients objected to restrictions on the distribution of experimental medicines and the design of clinical trials. But the struggle eventually died down as the leaders of patient organizations were invited to advise scientists and physicians on a more humane organization of research.[5] This lay intervention added a new ethical dimension to scientific practices that were not well conceived from the standpoint of current values. The changes were also cognitively significant since they made it easier to recruit human subjects and to insure that they cooperated in supplying researchers with the desired information.

These are American examples but other cases and other institutional procedures in other countries confirm the general pattern: from indifference to paternalism to signs of democratic engagement between science and society. If this trend develops widely, it promises to make a lasting contribution to democracy in technologically advanced societies.[6]

Technology and Society

I have left an ambiguity in the above history. I cited a weapon, a toxic waste site, and a disease. Both science and technology were involved in these technoscientific examples but too often they are treated as illustrating the disastrous consequences of science alone. In my view it is a mistake to focus exclusively on the relationship between science and society in discussing cases such as these. That approach emphasizes the cognitive aspect of the relationship and obscures the problem of authority. But

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[4] Feenberg, Andrew (1999). *Questioning Technology,* chap. 3. New York: Routledge.

[5] Epstein, Steven (1996). *Impure Science*. Berkeley, University of California Press.

[6] Callon, Michel, Pierre Lascoumbes, Yannick Barthe (2001). *Agir dans un Monde Incertain.* Paris: Seuil.

when science leaves the laboratory and enters society as technology, it must serve many other interests besides the interest in knowledge. As we have seen, technology is a field of activity in its own right. It is not a mere application of science. Industrial organizations intervene between the work of scientists and their technoscientific products. These organizations are independent mediations with their own logic and procedures. Technical creation is far less protected from lay intervention than is science in its cognitive role.

In those fields properly described as technosciences the situation is complicated by the ambiguity of the various activities involved in research and commercialization. When the actors seek more autonomy, they claim to be doing science; when they seek financial support they claim to be engaged in technology. Jessika Kammen describes an interesting case where researchers working on a contraceptive vaccine attempted to offload all the difficulties onto complementary "technologies" while reserving the title of "science" for their work. The distinction enabled them to continue pursuing the vaccine without worrying about the practical obstacles to its actual deployment.[7] Here the distinctions we are working with become political resources, but this should not blind us to what is really at stake in the case Kammen analyzes, namely, the welfare of millions of women and their families.

The reason for the difference between the role of the public in science and technology is simple. While scientific theories are abstractions and experiments are confined to the lab, technologies supply environments within which ordinary people live. Experience with these environments is a potential source of knowledge as we have seen, and everyday attitudes toward risk and benefit prevail there. All this distinguishes lay publics from scientists and technologists whose knowledge is formalized and who evaluate risks and benefits with mathematical tools.[8]

Bridgman simply dismissed the public as "stupid," but this is no longer possible. All too often lay observers have turned out to be the canaries in the mine, alerting scientists to overlooked dangers. And scientific and technical disciplines contain many traditional elements introduced during an earlier state of the society and its culture. In the case of technology the persistence of these elements past their time sometimes causes harm and motivates challenges from below that bring the tradition up to date.

Consider the huge variations in obstetrics from one time and place to another. Not so long ago husbands paced back and forth in waiting rooms while their wives gave birth under anaesthesia. Today husbands are invited into labor and delivery rooms and women encouraged to rely less on anaesthetics. The result of scientific discoveries? Hardly. But in both cases the system is medically prescribed and the role of the feminist and natural childbirth movements of the 1970s that brought about the change forgotten. A technological unconscious covers over the interaction between reason and experience.

There is a further distinction between the relation of science and technology to society. Even when they employ scientists and scientific knowledge, corporations and government agencies should not enjoy the relative autonomy of science. Their products give rise to controversy not about ideas but about potential harm. Those in the best position to know are usually associated with the very organizations responsible for the problems. But these organizations cannot be trusted to tell the truth or to act on it. Of course many corporations and agencies are honest, have the public welfare at heart and act accordingly, but it would be imprudent to generalize from such instances to the conclusion that vigilance and regulation is unnecessary.

The dominant feature of this relationship is the potential for conflict of interest. Familiar examples are the manipulation of information and the manufacture of artificial controversy by the tobacco

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[7] Kammen, Jessika (2003). "Who Represents the Users? Critical Encounters between Women's Health Advocates and Scientists in Contraceptive R&D," in N. Oudshoorn and R. Pinch, eds., *How Users Matter: The Co-Construction of Users and Technology,* Cambridge, Mass.:MIT Press, pp. 151-171.

[8] Collins, H. M. and Robert Evans, "The Third Wave of Science Studies: Studies of Expertise and Experience," *Social Studies of Science* 32/2(April 2002) 235–296.

industry with respect to lung cancer and energy companies with respect to climate change.[9] Conflicts of interest in such cases give rise to political struggles over regulation and, unlike scientific controversies, we do hope democratic procedures will decide the outcome rather than a "core set" of actors, namely, the corporations and agencies involved.

There is thus an enormous strategic difference between the science-society and the technology-society relationships. No matter how extensive the many interdependencies of scientific research and technology, no matter how blurred the boundary between them may sometimes be, there remains a fundamental difference with real consequences. In the case of scientific research we may value public input on occasion but leave scientists to draw their own conclusions. We may suspect particular scientists of incompetence or chicanery and ask for second opinions, but in the end we must rely on the scientific community. We do not have a similar confidence in corporations and governments. When they order up "truths" on command the results are disastrous. Nothing has changed in this respect from Lysenko to HIV denial in South Africa.

As public institutions corporations and government agencies, including those that employ scientists, must submit to democratic control of their activities. That control is often extensive and detailed and needs to be where their products circulate widely with significant public impacts. Thus we do not want an oil company or a government agency rather than scientists to decide if climate change is real, but we are not worried when the government orders a medicine off the market or bans a pesticide. Such decisions are a normal exercise of governmental authority and easily implemented by technical workers because, as noted above, so many viable alternatives are generally available.

The danger in confusing the cases is that when we demand democratic intervention into "technoscience," we will be understood to blur the line between cognitive and regulatory issues. Unless we keep these issues clearly separate we will appear to be irrationalists rejecting science when in fact we need it precisely in order to control the activities of technological actors such as corporations.

Differentiation and Translation

These reflections on the changing relation of science and technology are aspects of a much larger transformation of modern societies. Modernity has been characterized by sociologists since the end of the 19th century as a society in which social functions are highly differentiated. The obvious example is the differentiation of offices and persons. In a feudal society offices are family property and are inherited, whereas in a modern society individuals must qualify personally to hold offices which they cannot leave to their children. When dictators promote the succession of their sons or voters favor the children of prominent leaders, we immediately sense incipient de-differentiation, a suspicious cultural throwback.

Differentiation makes modern science and technology possible. The emergence of scientific specialization and the separation of technical work from everyday life mark major milestones in the process of modernization. The case of technical work is particularly significant for understanding the problems of modern societies. In premodern Europe crafts were organized by guilds that had social and religious functions as well as regulating training, quality control, and standards. The crafts of this period were thoroughly integrated with society and craftsmen communicated easily with the authorities and customers using everyday language and traditional concepts shared by all. Indeed, many craft products required finishing by users who thus participated in a small way in the production process. Remember "breaking in" smokers' pipes, shoes and car engines, bygone practices for which few are nostalgic.

Differentiated technical work draws on specialized scientific knowledge and speaks a language inaccessible to the mass of users of its products. At the same time, the stripping away of social concerns, such as preoccupied the guilds, breaks the last links between technology and tradition. Instead, most technical work is now situated in the context of capitalist enterprise. This has dramatic consequences we are only beginning to fully understand.

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[9] Michaels, David (2008). *Doubt Is Their Product: How Industry's Assault on Science Threatens Your Health*. Oxford: Oxford University Press; Oreskes, Naomi and Erik M Conway, *Merchants of Doubt: how a handful of scientists obscured the truth on issues from tobacco smoke to global warming*, Bloomsbury Press, New York, 2010.

Capitalist ownership is also affected by the process of differentiation. Owners of property, especially land, in precapitalist societies had broad responsibilities to tenants that included political, judicial and religious functions. These are all stripped away as capitalism defines a new concept of ownership based on personal labor. This new concept of ownership focuses the organizations capitalism creates, the corporations, factories and stores, on a single simple goal: profit. Responsibilities to workers and the surrounding communities are abandoned.

The industrial revolution occurred under this dispensation. A heritage of indifference to nature and human beings lies in the background of the development process from which modern technology first emerged. Throughout the process capitalism drew on specialized scientific and technical knowledge for innovative ways of making a profit. The narrowness of these specialized bodies of knowledge complemented the narrowness of the structure of ownership. A sharp focus on a vastly simplified view of the problems to be solved with technology accelerated progress while also multiplying unexpected side effects.

So long as those harmed by this process were too weak or ignorant to protest, the juggernaut of capitalist technology could go forward unimpeded. But in the post World War II period, two new trends emerged. On the one hand, the technologies became far more powerful and dangerous, causing more frequent and visible harm. This trend culminates in the technosciences which transform science and technology into a powerful productive force. Their unity can be understood as an original type of de-differentiation. It does not involve regression to an earlier undifferentiated state but advance to a new configuration in which the interpenetrating institutions greatly enhance each others' powers.

On the other hand, as technical transformations affect more and more of social life under this new dispensation, unions and social movements became more influential and regulation of industry more widely accepted as a normal part of political life. As a result, a slow compensatory process begins which continues down to the present. This process is also de-differentiating and compels industry to respond to a wider range of values and functions than profit, or rather, compels it to seek profit under an ever widening range of constraints. At the same time, this process also encourages various interdisciplinary scientific initiatives which attempt to encompass the full range of effects of our action on the environment and the human body.

It is in this context that we discover the many conflicts between technology, the environment and human health. These conflicts do not arise from the essential nature of technology but from the confluence of specialized knowledge and the narrowing of social responsibility characteristic of capitalist ownership. As we attempt to move forward toward a reformed technology, the role of everyday experience in technoscience and technology is re-evaluated. Where formerly cognitive success required breaking all dependence of technical knowledge on everyday experience, experience now appears as a final court of appeal in which technical knowledge must be tested.[10] The limitations and blind spots of specialized knowledge are no longer routinely smoothed over and ignored. They have become targets of questioning and protest as users and victims of technology react to the suffering they cause.

This and not hostility to science and technology explains the new climate of opinion in which the autonomy of scientific and technical institutions is increasingly challenged. The goal of these challenges is a science and technology that responds to the claims of the environment and human health and not just to profit and the technical traditions built up under the influence of capitalism. This aspiration can only be fulfilled through a long corrective process in which the return to experience for validation of technology focuses attention on those of its effects which were ignored as it was differentiated from everyday contexts to create specialized disciplines and to better serve capitalism. The return to those lost contexts is no relapse into romantic immediacy, but requires ever more complex social and technical mediations.

This process cannot succeed through destroying the institutions within which science and technology have developed. Rather, it must develop its own institutions for translating social knowledge about technology's harmful effects or overlooked potentialities into new technical specifications for better

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[10] Wynne, Brian (2011). *Rationality and Ritual: Participation and Exclusion in Nuclear Decision-Making.* London and Washington D.C.: Earthscan.

designs. These institutionalized modes of intervention are gradually emerging. They include protest movements and lawsuits, but also various forms of apriori participation in debate and design which attempt to inform technical work before products are released on the public. The routinization of the translation process is a foreseeable outcome of these activities. Translation in this sense completes the circle in which technology modifies society while itself being modified by society. This is an important democratic advance.