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DOSSIER

Technoscience and the dereification of nature[1]

Tecnociência e a desreificação da natureza

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ABSTRACT

The many definitions of technoscience are offered as correctives to an ideal of pure science, completely separate from society. The critique of purity in Science and Technology Studies was preceded by phenomenological critiques in Heidegger and Marcuse. The idea of purity is no longer credible. Yet the concept of pure science has played a role historically in defending science against political interference. The concept of technoscience risks opening science to such interference and has provoked a renewed and rather futile defense of its purity. The consensus in STS that science is fundamentally social seems to obviate the need for a term such as technoscience. This paper suggests a restrictive definition of technoscience based on the multiplication of independent tests of validity. This is an extreme case of the sociality of science because here science and technology emerge together rather than theory preceding application. Technoscience under this definition would describe scientific work, validated scientifically, that serves *simultaneously* in commercial and public processes which have their own independent logic and tests of validity. Under this definition, the existence of complex interactions between science and society does not blur the boundaries between these tests. Technoscience is embedded in society like all science, but is unique in standing at a "fork" between distinct languages and criteria of success.

Keywords: Technoscience, STS, Heidegger, Marcuse, science/society.

RESUMO

As muitas definições de tecnociência são oferecidas como corretivas para um ideal de ciência pura, completamente separada da sociedade. A crítica da pureza nos estudos de ciência e tecnologia foi precedida por críticas fenomenológicas em Heidegger e Marcuse. A ideia de pureza não é mais credível. No entanto, o conceito de ciência pura tem desempenhado um papel histórico na defesa da ciência contra interferências políticas. O conceito de tecnociência corre o risco de abrir a ciência a essa interferência e tem provocado uma defesa renovada e fútil da sua pureza. O consenso nos estudos de ciência e tecnologia de que a ciência é fundamentalmente social parece obviar a necessidade de um termo como tecnociência. Este artigo sugere uma definição restritiva de tecnociência com base na multiplicação de testes independentes de validade. Este é um caso extremo da sociabilidade da ciência, porque aqui a ciência e a tecnologia emergem juntas, em vez de a teoria preceder a aplicação. A tecnociência sob essa definição descreveria o trabalho científico, validado cientificamente, que serve *simultaneamente* em processos comerciais e públicos que têm sua própria lógica e testes de validade independentes. Sob essa definição, a existência de

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interações complexas entre ciência e sociedade não obscurece as fronteiras entre esses testes. A tecnociência está inserida na sociedade, como toda ciência, mas é única ao se situar em um "garfo" [ataque duplo no xadrez] entre linguagens distintas e critérios de sucesso.

Palavras-chave: Tecnociência, estudos de ciência e tecnologia, Heidegger, Marcuse, ciência/sociedade.

Two images of science

The first Western philosopher, Thales of Miletus, figures in two stories that illustrate very different images of science. In the first of these stories Thales is an ivory tower thinker. It is said that one night as he surveyed the heavens, he slipped and fell into a ditch. An old woman passing by laughed and asked how he could understand the stars when he failed to see what was right there under his nose. This is the popular image of pure science that prevailed also in philosophy and social thought until fairly recently. But there is another story which projects a very different image of science. It is said that Thales studied the weather in his home town and one winter predicted a bumper olive crop. He optioned all the local olive presses and when the crop came in, he made a fortune renting them out at a profit. This version of Thales anticipates the alliance of science and business that prevails today.

The ivory tower image was based on a certain understanding of theoretical physics, the most basic of basic sciences. Theoretical physics is a mathematical discipline that appears on the surface very remote from the world of technology, both in terms of applications and experimentation. Physicists in glorious isolation were said to input data from experiments in their equations, leaving the applications to engineers and other lesser under-laborers.

This image of physics as a pure intellectual discipline was supported by positivist philosophy of science which became dominant in philosophy departments in the English-speaking world after World War II. In the 1980s scholars in the field of Science and Technology Studies (STS) took up the term "technoscience" in reaction against positivism.[3] The philosophers who popularized the term proposed a more realistic image of science compatible with Thales the scientific entrepreneur. They argued that science is essentially connected to technology, that it has always had an applied aspect and that its vision of nature depends on what can be done with technological instruments. This concept of technoscience usefully corrects the notion of pure science.[4]

However, there is a tendency to overstate the case, to try to obliterate the distinction between science and technology. "Technoscience" is a confusing term if it is intended to obliterate the obvious differences between scientific research and most work with technology. Those differences cannot be erased by a clever terminological invention. Although they all use technology, the problems faced by truck drivers and construction workers are rather different from the concerns of theoretical physicists. Blurring the distinction is worrisome because it opens the door to political regulation of science on the same terms as technology. Routine regulation of technology protects us from many hazards, but one would not want scientific theories to be subject to politics in the same way. The Russians tried this with genetics and killed the science in their country for 50 years.[5] Today Trump engages in the political manipulation of climate science.

Some definitions of technoscience emphasize the epochal change that results from the breakdown of the divide between nature and culture in our time. Science no longer studies a supposedly pristine nature but rather artificial materials such as computers and nanotechnologies. Experimentation used to place natural phenomena in an artificial environment but today in fields such as particle physics the phenomena are actually produced for study in huge machines.

The emphasis of research may indeed have shifted but the refining of metal ores crossed the nature/culture divide in the bronze age. Plant and animal breeding go back much further and similarly blur the boundary between nature and culture. The claim that an epochal change has occurred in the relation of nature and culture is less relevant to science than to industry, where the scale of human intervention is now much greater than in the past.

Other definitions of technoscience claim that science is now fully incorporated into the corporate and public processes of advanced societies. Certainly the involvement of business and government in research has expanded enormously in recent years. But the epistemic implications of this evolution are in dispute. This concept of technoscience is sometimes articulated in terms of post-modern relativism, as though the establishment of a scientific theory could be compared to business success. The "Science Wars" were provoked by such notions. The dangers of such a relativistic view are becoming clear with the election of science skeptics such as Trump and Modi. Yet there is surely a connection between science and society and that connection is perhaps deeper today that at any time in the past.

[3] The invention of the term "technoscience" has been attributed to Gaston Bachelard. See Gaston Bachelard, 1953. Gilbert Hottois introduced "techno-science" in his 1986 book *Le Signe et la Technique*.

[4] For this and the other versions of technoscience discussed here, see the essays in Alfred Nordmann *et al.* (eds.), 2011.

[5] See Loren Graham, 2016.

In what follows I will propose a qualified version of this last definition of technoscience, one that I think is useful for understanding the political implications of the engagement of science and society, while avoiding the relativism sometimes associated with that concept. I will begin now with a little personal history that helps to understand what is right about the basic idea behind the concept of technoscience.

The ambiguities of technoscience

This is personal because I grew up in the midst of theoretical physics. My father was one of the young students sent by American universities to Germany in the 1930s to learn quantum mechanics at the source. Unwittingly, these universities prepared America for war. In 1939 Einstein wrote to Roosevelt proposing that the US attempt to develop an atom bomb. In 1942 the Army Corps of Engineers initiated the Manhattan Project. Around this time a colleague came to visit my father and asked where they could speak in absolute privacy. On the roof of our New York apartment building he extended an invitation to join the Manhattan Project. My father declined for reasons he never really explained and instead went to work on the development of radar.

During the war, he patented several improvements in a special type of vacuum tube called a klystron. This is a very powerful generator of shortwave radio waves used in radar. Some years later, when I was about 10 years old, my father was invited for the summer to Stanford University where the klystron was invented. There he and his colleagues worked on the design of the Stanford Linear Accelerator, a high-energy machine that accelerated electrons to relativistic velocities. The wife of one of his Stanford colleagues organized a crystal radio club for the children of the physicists. While the dads were working with radio waves generated by klystrons, we kids were busy figuring out how to detect a radio signal with a chunk of silicon.

What is the point of the story? Theoretical physics may well resemble the positivist idea of purity, but it was no problem for a theoretical physicist to work on technology at his country's call. One would not expect a sociologist or a French professor to find this such an easy transition. And it was also possible for that work to lead to new instruments for detecting features of nature that had never before been seen, leading to further progress in pure science. Here the usual concept of technoscience is validated in its main outlines.

But the introduction of the concept in the context of the polemic against positivism has obscured the social function of the notion of pure science. The sharp division between theory and application was instituted by the nineteenth century research university. Pure science was granted the dignity of a disinterested search for truth and located alongside fields such as philology and history from which no practical or pecuniary application was expected. This supported the independence of science and the right of scientists to engage in basic research. Scientists saw themselves as intellectuals involved in higher culture on terms similar to literary scholars or historians. Of course there have always been important applications of science, even as it was institutionalized in the ivory tower in the late nineteenth century. That was when great scientists invented vaccines and artificial dyes. But maintaining the idea of pure science was still important for legitimating work that had no obvious practical value such as, for example, the special theory of relativity.

The emphasis changed after the Second World War. Three scientific innovations played an important role in the allied victory. These were the atom bomb, radar, and cryptography. After 1945 the American military saw science as a key to victory in the Cold War. The US government proposed to fund science while bringing it under direct military control. This would have involved rigorous security, secrecy, and draconian punishments for violations of the new regulations. Scientists resisted and succeeded finally in creating the current system of grants and contracts administered by universities.[6] In this way they protected their independence while benefiting from the vastly increased funding available for scientific research. The ideology of pure science played an important role in the success of this compromise with the military. Let the scientists pursue what Vannevar Bush called the "endless frontier" of research in the university, and eventually useful applications will trickle down, as indeed they did. From this point of view one sees the advantage of positivism. By isolating science completely from the world of technology one protects it from intrusive regulation.

The fact that the personal experiences and activities of scientists contradicted the ideological notion of pure science was easily overlooked. The purity of so-called pure science was no obstacle to scientists relying on ever more complex technologies in their exploration of nature while contributing ever more applications to the military and business. But the gap between the idea of pure science and the technoscientific reality has widened in recent years. The biological sciences are now the model science, replacing theoretical physics. The distinction between pure and applied science breaks down in biology to an unprecedented degree. A great deal of biological research is directly supported by pharmaceutical companies and other businesses that are not engaged in a disinterested pursuit of truth but rather seek profitable products. And while much progress has been made, the consequences are exactly what the scientists feared from military control, namely secrecy and corruption of research by external forces.

In an earlier paper, I suggested a restricted definition of "technoscience" based on these considerations (Feenberg, 2018).[7] I proposed that we reserve the term for scientific re-

[6] The story is told by Alice K. Smith in the book *A Peril and a Hope*, 1965, chapter 10.

[7] See also Feenberg, 2009, p. 63-81.

search that has an *immediate* role in the development of applications of some sort. In such cases theory and application are not separate phases that proceed in isolation from each other at separate times and places, but are pursued simultaneously. I compared this situation to a "fork" in chess, a move that threatens two of the adversary's pieces. This is the case, for example, where the experimental apparatus is a prototype of a future technology. In such cases the innovation must satisfy two separate audiences with different criteria of success, the scientific community and the commercial partner.

Cold fusion served as my example, because in that case the experimental apparatus was treated as a commercial prototype. Cold fusion failed the epistemic tests to which it was subjected and the whole project collapsed. I could also have referred to any number of research programs in medicine, some of which do succeed, unlike cold fusion. The point is that in such cases there is no need to wait for a subsequent application of scientific principles because the research *is* the application. Here the relation between the two defies the differentiation of science and society without violating the epistemic criteria of scientific success. In the concluding sections of this paper I will propose a broader application of the notion of technoscience as a fork between science and society. This generalization of the concept recognizes the increasing dependence of public understanding and action on scientific research and the simultaneous participation of the public in orienting that research.

Transcendental technoscience

So far I have been describing the social world of science. The concept of technoscience in all its various formulations introduces a more realistic picture of that world than the earlier vision of pure science. But it also raises a fundamental question. What is it about scientific thinking that lends itself so readily to technological application? What is it about science that ties it to a world seen through technology? Something more basic than social history is necessary to answer these questions. I want to now consider several philosophers' explanation for the deep connection between science and technology.

That connection was announced early by Descartes and Bacon and was associated with the idea of progress. But in the early 20th century a critical discourse arose, associating science and technology with the reduction of human beings to cogs in a vast social machine. This dystopian prospect achieved a sophisticated formulation in the post-war writings of Martin Heidegger. His former student, Herbert Marcuse, pursued the critique of science and technology in an alternative to Heidegger's formulation.[8]

Heidegger and Marcuse share a key concept, the transcendental notion of object construction. According to this notion, each field of research defines a specific kind of object through its methods and concepts. In one sense this is obvious. Physics for example considers matter in motion while biology considers life, and so on. But these philosophers regard such definitions as only the beginning of a far more detailed specification of the way in which a certain cross-section of reality is carved out for investigation. That refined cross-section constitutes the object of study.

Both of these philosophers introduce history into the transcendental approach. Kant, who invented the transcendental approach, explained it as an operation the subject performed on the givens of experience. Transcendental forms were said to be imposed by the mind on a content such as raw sensations. But Heidegger and Marcuse agree that the forms change in history. Heidegger calls the succession of such forms "the history of being" and Marcuse attributes the changes to the evolution of modes of production. In both cases an anonymous historical process rather than an individual mind is responsible for the imposition of form on content. Perhaps this approach should therefore be called "quasi-transcendental" since the source of the forms is changeable and, in Marcuse's case, inner-worldly.

Neither Heidegger nor Marcuse deny that science studies reality, but given the role of the subject in object construction, common sense realism is excluded. Furthermore, there is no reason to grant science an exclusive license on the truth of the real. Other object constructions may reveal other truths, hidden to science by the limitations of its own construction.

Heidegger argues that modern science projects a quantifiable idea of nature that is intrinsically oriented toward technical control. He calls this a "ground plan" that anticipates in advance the sorts of things that can appear as objects of research. His example is physics for which nature is stipulated to consist of a self-contained system of motion of units of mass related in time and space. Motion here means only change of place in a uniform continuum. This definition of the object suits it to the establishment of exact mathematical measurement. Modern science relies on mathematical procedures since it defines its object as the sort of thing that can be measured and counted.

Heidegger argues further that modern science produces an image or representation of the world. He calls this a "world picture," that is, a supposedly exhaustive representation of reality. This seems self-evident: science gives us an image of the cosmos we accept as a more or less accurate picture of reality. But according to Heidegger this is a uniquely modern way of understanding the real. It makes possible prediction and technical manipulation. The interconnection of science and technology lies in the original ground plan which exposes nature to both representation by science and control by technology.

Modern and ancient science are radically different.[9] The difference stems from their conceptions of nature. The

[8] See Martin Heidegger, 1977. See also Herbert Marcuse, 1964, chapters 5 and 6. For my interpretation of these chapters, see Andrew Feenberg, 2013, 604-614. See my discussion of these thinkers in Andrew Feenberg, 2019, chapter 9.

[9] See Heidegger, 1977.

ancient concept, exemplified by Aristotle's *Metaphysics*, is derived from biological growth and craft. It corresponds closely with the everyday ontology that phenomenology describes as the *Lebenswelt*. Ancient Greece did not identify the essence of reality with a representation, a picture, but with a process. The Greeks encountered a self-creating, self-moving nature consisting of relatively stable things that realize their intrinsic potentialities through change. This nature has a life of its own independent of the subject. This developmental process cannot be measured in quantitative terms and gives rise to no theoretical representation. The same word, *kinesis*, signifies these qualitative changes and mere movement in space such as our science recognizes.

The modern scientific picture of nature eliminates self-movement and intrinsic potentiality. Nature is meaningless and utterly dependent on the subject for which it serves as a raw material dominated through instrumental control. Heidegger calls the reduction of the world to manipulable resources the *Ge-stell*. Modern technology thus differs from ancient craft, which realizes potentialities of nature that nature cannot realize by itself. The *technē* of a craftsman must intervene in bringing those potentialities into actuality. No such mutual interaction of subject and object is involved in the *Ge-stell*.

Heidegger intended this theory to be critical but not anti-scientific. What troubled him was the absorption of the human being into the ground plan of science as just another object exposed to representation and control. But he did not criticize science for this but rather the spirit of the modern age and its understanding of science. This critique of modernity leaves very little room for alternatives.[10] Heidegger would have rejected anything resembling "New Age" re-enchantment. Using myth or religion in order to reestablish meaning in life would simply instrumentalize these spiritual resources and so recapitulate the original problem of universal technification. He offered no way out and in his last interview said "only a God can save us" (Heidegger, 1993).

I turn now to Marcuse's alternative approach which has much in common with Heidegger's but offers a more hopeful prospect. Marcuse's discussion of science follows more or less along the lines laid out by Heidegger. He too argues that science is based on a concept of nature which exposes it to quantification and control. He quotes Heidegger as saying, "modern man takes the entirety of being as raw material for production and subjects the entirety of the object world to the sweep and order of production" (Marcuse, 1964, p. 153). The essence of modern science is the elimination of intrinsic potentiality in favor of measurable facts. The Greeks conceived potentialities as real properties of objects, essences, but essences are now dismissed as mere cultural prejudices. Our model of technical action is not cultivation but clear cutting. Since reality no longer offers any guidance for action, all goals appear equally arbitrary and science and technology are surrendered to the prevailing social and economic powers.

Marcuse's analysis differs from Heidegger's in arguing that this instrumentalist conception of nature is due not to modernity as such but specifically to capitalism. He follows Husserl in arguing that science refines and develops practices of quantification and control it finds in everyday life. Marcuse adds that those practices are shaped by capitalism. This would explain why modern science and technology have arisen at the same time as capitalism and serve it well.

What Marcuse calls "one-dimensionality" is the generalization of scientific instrumentalism as common sense, replacing traditional normatively charged ideas and attitudes that formerly shaped the everyday relation to the world. This change is politically significant. If the world is reduced to a vast collection of measurable facts subject to technical control, its potentialities are obscured. It can be modified technically in this or that respect but not fundamentally changed. Operationally effective reforms can eliminate the desire for change short of any challenge to the capitalist organization of social life. The problem is thus not only the destructive power of science and technology but the elimination of the potential for a more just form of society.

Attributing the rise of science to a specific socioeconomic system suggests the possibility of change through political action. Marcuse was a Marxist who believed that a revolution would modify not only economic arrangements but the very conception of nature. A socialist modernity would integrate science and art in a new, more benign technology respectful of nature. This would be the revival of something like ancient *technē*, and with it the recovery of the idea of potentiality, banned from the modern scientific idea of nature and modern experience (Marcuse, 1964, p. 238-240).

Marcuse's position appeals intuitively to our sense that things have gone terribly wrong in recent times despite, or perhaps he would say, because of the many reforms that have made life under capitalism tolerable. Furthermore, an ontology that denies essences contradicts our sense that human beings have potentialities that can be frustrated or realized depending on their social and economic circumstances. Nature appears to us increasingly threatened by our crude technological assault on its integrity. In some sense this suggests that nature too has potentialities we can favor or deny.

Nevertheless it is difficult to see how modern science could function in the context of a different concept of nature. Marcuse seems to have been aware of the difficulty because he rejected the notion of a qualitative physics. That would be a science like Aristotle's that identifies the essential potentialities of things rather than measuring them. So how does Marcuse intend to avoid regression to such a qualitative

[10] Heidegger is infamous for having imagined that Nazism could be such an alternative. He was quickly disillusioned with the regime but never gave up his own personal version of Nazi ideology. This testifies to a despicable character flaw, but his critique of modernity is similar to that of many who did not share his political views and need not be dismissed on that account.

science? Furthermore, in the absence of a scientific ground for the identification of potentiality what grants our notion of it objective status? Aristotle did not have to address these questions because he took his culture's conventional ideas of potential for granted. Nor was this a problem for Heidegger since he left the future in the hands of God. But Marcuse projects a human future, humanly created in harmony with the potentialities of nature and human nature and so faces great theoretical difficulties.

The two natures

Behind the arguments of Heidegger and Marcuse there lies a sense of loss. What is lost is the immediate relation to living nature that can be presumed to characterize premodern times. The scientific representation of nature is radically simplified in being reduced to a collection of measurable facts. The generalization in public understanding of that simplified nature impoverishes experience. Heidegger writes, "The botanist's plants are not the flowers in the hedgerow; the 'source' which the geographer establishes for a river is not the 'springhead in the dale'" (Heidegger, 1962, p. 100). As Goethe's Mephistopheles says, *"Grau, teurer Freund, ist alle Theorie und grün des Lebens goldner Baum"* (Goethe, 1962, p. 206).[11]

Walter Benjamin explained something similar in the context of film production. His remarks can be taken as referring metaphorically to modern life:

> *In the studio the mechanical equipment has penetrated so deeply into reality that its pure aspect freed from the foreign substance of equipment is the result of a special procedure, namely, the shooting by the specially adjusted camera and the mounting of the shot together with other similar ones. The equipment-free aspect of reality here has become the height of artifice; the sight of immediate reality has become an orchid in the land of technology (Benjamin, 1969, p. 233).*

In this new technological world, Heidegger feared that human beings had come to see themselves as mere resources. Marcuse feared that modern consciousness was incapable of going beyond the given facts toward their potentialities. The dystopian perspective of these philosophers was justified by the seemingly universal acceptance of the technified world. At the time they wrote, there was practically no resistance to the developing technocracy and social movements that challenged science and technology, such as the environmental movement, were very small. Social science was so strongly imbued with positivism that it offered no useful starting point for the sort of reforms Marcuse envisaged. Only philosophy and literature held out for humanity, and they were weak vessels on which to pin one's hopes.

So much resistance has emerged in recent years that the fears of Heidegger and Marcuse no longer seem justified, but nature's orchids have not been recovered. Those resistances defy the one-dimensional reduction of experience and activate the perception of a nature with potentialities relevant to human well-being. This is the consequence of the threats to health generated by the externalities of industry. Experiential nature thus emerges amidst the world of technology as Benjamin supposed, but negatively, not as pristine but as damaged. This nature is neither the object of science nor the wilderness of earlier times, but a specialized function of the technological environment.

The relation to nature implied in environmentalism is not the detachment of the researcher, nor the instrumentalism of the investor, but is divided between fear of technological risks and aesthetic appreciation. The challenge of the environmental movement is to awaken these human relations to nature in a social world that privileges economic exploitation, considers only scientific objectivity valid, and stigmatizes fears as "hysterical" while dismissing aesthetics as "romantic." What Marcuse calls the "erotic" world relation environmentalism must restore is the capacity to recognize our participation in the natural world through revulsion at its destruction.

Today we have concrete ways of envisaging the reform of science for which Marcuse called based on actual social movements in domains such as environmentalism. These movements restore what we might call the "Aristotelian" sense of nature, as fraught with potentialities, and recall human beings to their responsibilities toward that nature. But this development does not directly alter the scientific object as Marcuse expected. Rather, it engages science with society in new ways. The historical divide between two different ideas of nature, the ancient and the modern scientific, must now be recomposed as a tension within modernity.

The environmental movement is based on the distinction between the two natures, derived not from philosophy but from practical experience. The nature environmentalists hope to protect is the one in which they participate, the experiential nature encountered in everyday life. It has a teleological aspect science does not recognize, yet it depends for its survival and well-being on scientific and technical knowledge. The scientific representation of nature is radically simplified, but that second nature, as the basis of technology, gives power over the first nature of everyday experience both for good and ill.

Not only does scientific nature offer remedies for environmental problems, it enters into the public understanding of those problems. It is not unusual for science to have an impact on public understanding. Think of the impact of geology and evolutionary theory on the place of religion in social life. Heidegger and Marcuse believed aspects of the scientific

[11] "Gray, my dear friend, is every theory, And green alone life's golden tree."

worldview had penetrated everyday understanding, cancelling the specificity of experiential nature. But in the case of environmentalism the connection is more entangled: public understanding is based on scientific concepts that interpret the actual data of lived experience without cancelling its teleological form. The two natures enter into communication.

Concepts such as "pollution" are no longer just technical terms but join the vernacular in the description of experience. Nature is now conceived in its relation to the whole sociotechnical network to which it belongs, and not simply as non-social "stuff" available as a resource. What we might call its "Aristotelian" character reappears prominently as its condition is evaluated in teleological terms: nature is sick or healthy, abused or protected. Experiential nature, unlike scientific nature, has potentialities that can serve as normative criteria. This is the "existential truth" of nature Marcuse postulates but in a different form than he imagined (Marcuse, 1972, p. 69). These potentialities are relative to human perceptions and needs, so they are easily dismissed as anthropomorphic from a scientistic standpoint. But they are none the less real in the sense that they are physically manifest in the natural world that can be perceived and touched.

Growth is a property of living things that appears differently to science and everyday experience. The stream full of trout is no illusion and its flourishing is a real quality of its being in the same way that the flourishing of a plant or a child testifies to an underlying reality. Science describes the process from stage to stage but rejects any teleological explanation or normative evaluation of the result. Everyday experience sees a progress toward an end, the fulfillment of a potential. Such teleological perception organizes a good deal of human interaction with the surrounding world. It is not "subjective" in the pejorative sense but gives access to a different aspect of reality from science. With environmentalism these two natures are in communication. The scientific nature facilitates the restoration of the *telos* of the lived nature of everyday experience.

The climate change movement illustrates these conclusions. Climate disasters such as hurricanes present themselves ambiguously, as either normal variations in the weather or as evidence of impending catastrophe. Climate science disambiguates these experiences and provides ideas and a language in which to express the increasing anxiety individuals feel in the face of experiential nature. The public does not perceive its situation with the detachment of science, but rather in terms of the potentialities of nature to support civilization. The two natures come together and motivate public protest in favor of radical technological change. The "fork" between science and society where research is simultaneously theory and technology appears here in the imbrication of the two natures.

Technosystem

What I call the "technosystem" is the vast concatenation of organized markets, bureaucracies, and a wide-ranging technical apparatus that organizes life in advanced capitalist societies (Feenberg, 2017). All these institutions and technologies are based on technical disciplines which take the form of sciences even if, as in the case of management science, they have little claim to a scientific basis. Reified concepts and methods are employed to shape a world based on "laws" regulating the behavior of individual actors cast in an instrumental relation to the institutions. Throughout the technosystem resistances emerge similar in form to the environmental movement in fields such as medicine and urban design.

Reified technology appears as a pure application of scientific laws, but that appearance is shattered by one or another sort of public pressure and resistance. The technology can then be mediated, that is, taken as a presupposition of social action, and transformed in the course of the iterative design process. The process is also dedifferentiating as the boundaries between technical experts and lay publics break down temporarily to yield to a more or less conflictual dialogue between them. This dialogue results in changes in the prevailing designs, implemented by experts through innovations that translate public demands into technical specifications.

The dereification of particular technologies may impact the technosciences on which they depend. These disciplines appear fixed and frozen, determined by pure rationality. But despite the appearances, new priorities articulated by social movements can change the discourse. Demands for such things as less polluting automobiles or more "natural" childbirth procedures are eventually translated into technical terms and inscribed in the texts on the basis of which practitioners are trained. This is possible without loss of technical rationality insofar as the prevailing dispensation is technically underdetermined, only one among several technically rational configurations. The new dispensation is once again reified, presented in quasi-scientific terms. These new reifications may then be challenged in a subsequent public intervention.

Technosciences now proliferate that operate across the boundary between science, technology and politics maintained by academic institutions in the past. The intrinsic relation of science and technology is not just a function of the concept of nature, as Heidegger and Marcuse argued, but is also a present disciplinary reality. Technosciences that barely existed for these philosophers are now central to our vision of science. These disciplines respond to properly epistemic questions posed by researchers while simultaneously addressing other question posed by corporations, governments and the general public. And as Isabelle Stengers argues, these are all legitimate questions responding to different concerns and different understandings of nature (Stengers and Drumm, 2013, p. 129-134). Together they lay out the terrain on which science, technology and society now interact. These interactions are not just external but engage a mutual co-construction.

These effects are particularly clear in the early stages of the development of a technoscience, before its object has been firmly established. Consider ecology, which emerged in the form we know it today out of a confrontation in the early 20th century between organic holism and a non-teleological "materialist" conception of the ecosystem.

As Foster, Clark and York tell the story, two different ideas of nature contended for dominance in the new science (2010, chapter 14). One group of scientists proposed to found ecology on a natural "superorganism," organized in a hierarchy of forms according to teleological laws. Another group proposed a nature of multiple contingently related organisms governed by causal laws. The controversy had both epistemic and political dimensions. The holistic view was associated with a racially charged understanding of colonialism, while the alternative materialist view had affinities with socialism. In the end, the materialist view was both more productive scientifically and more in line with the contemporary conception of human rights. It successfully navigated the "fork" between science and the public. Materialist ecology answered two different types of questions, questions about patterns of interdependence between organisms, and questions about how to understand our humanity and the relation to nature it implies.

Ecology is not simply applied to policy, but arises from it. From the standpoint of "pure" science, the earth can get along fine without us, but ecology is predicated on the problem of human survival and serves that end by defining dangers and thresholds of change. To be sure, ecology employs the methods of scientific research. It conceives nature along the standard lines of physics, chemistry, and biology. Quantification lies at its core. But at the same time it is animated implicitly by what traditional philosophy would call a conception of the good. It translates into scientific terms bridging concepts of health and sustainability that refer to potentialities of its objects. These bridging concepts respond to concerns of citizens but they infuse the science by orienting it toward specific types of problems and measures.

Climate science, for example, is oriented toward predicting effects that will impact human civilization. Human beings have never had a merely idle interest in the climate. As the story of Thales and the olive harvest shows, the study of the climate was initially motivated by a pragmatic interest in agriculture. The climate was understood to be beyond human control but attempts to predict it never ceased. In 1896 Svante Arrhenius showed that human activities affect the climate, thus bringing the object "climate" into the scope of history. In recent years climate science has begun to guide interventions into the climate to maintain the conditions of human civilization. The object, "climate," has been constructed and reconstructed over and over again.

As awareness of climate change spreads among the population, social movements arise. The climate is not simply natural any longer, nor even historical, it is political. The politics aims to place a natural phenomenon on the agenda of public discussion. In democracies, there are familiar methods for accomplishing this, such as demonstrations, petitioning government officials, participation in hearings and elections, and so on. The object of all this activity is informed by science, but it is not precisely the same object as the one scientists study. Rather, the nature targeted by the social movement encompasses scientific nature in experiential nature. That latter nature is dereified in the sense that it is no longer viewed as a fixed and unchangeable object of measurement, a fate to which humanity must adjust, but now appears as fraught with potentialities to flourish and support human life. And that experiential nature in turn informs the research of climate science where it is translated into the humanly indifferent form of quantitative measures and predictions.

Technoscience in this sense answers Marcuse's requirement that science recover a notion of potentiality, but it does so differently than he imagined. We could extend this argument to other disciplines as well. Urban planning, architecture, epidemiology, medicine, some versions of management theory are all developed around a concept of the good of the populations they affect. And this good is not simply a subjective wish but flows simultaneously from the struggles of the individuals concerned and the study of human needs and capacities in the contexts in which these disciplines intervene.

Here the constitution of the research object and the uptake of theoretical knowledge in society form a single whole that cannot be disaggregated into mechanically separated parts. Of course there is a division of labor between different aspects of the network formed by science and society. But each aspect is defined by its relation to the other.

Conclusion

The empirical study of science by STS has made the point that the boundary between science and technology is less clear than was assumed in earlier times. Heidegger and Marcuse anticipated this conclusion. They posited a transcendental link between science and technology underlying the empirical trends traced by historians and sociologists. For them the point was not that science was applied or relied on instruments to perceive the world, but rather that science conceived nature as the sort of thing that could be measured and controlled.

While this led Heidegger to despair, Marcuse proposed an alternative concept of nature's potentialities. He argued that under socialism the scientific object construction would again include potentialities. But it turns out that we have not had to await a socialist revolution to see recognition of the potentialities of nature. Already the reaction against the destructive aspects of capitalist technology has motivated significant changes neither Heidegger nor Marcuse anticipated.

These changes affect both the sciences and the technologies that interact directly with nature. Sciences construct a nature artificially isolated from the social context, but that context returns when their technical products are implemented in the social world. The dereifying action of social movements for a sustainable future transforms nature as it is encountered historically. These movements address the technosciences in terms of a conception of potentiality that orients them toward new objects and new applications. The social contextualization of the scientific idea of nature affects research without violating its epistemic integrity.

In conclusion, the concept of technoscience embraces the new situation of certain sciences which produce knowledge at the same time as they have immediate effects on the social world. Those effects include technological applications that flow directly from research, but they may also take the form of changed attitudes and behaviors. The technosciences thus operate in two registers, as observers of nature and as participants in its transformation, both material and symbolic.

These two registers are institutionally differentiated to a considerable extent but meet through policy and public dialogue. The differentiation of science and society shows up in the fact that the work of scientists in elaborating and testing knowledge of nature goes on as it always has. The skills involved in that activity have not been affected by the new proximity of theory and practice. At the same time, the differentiation is transgressed in the constant translation between scientific concepts, technology and vernacular understanding. Those translations shape society and orient scientific work. This understanding of the concept of technoscience is relevant to disciplines such as ecology that incorporate science as we know it in a larger framework that recognizes what Marx called the "metabolism" joining humanity to nature.

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