ON THE GROWING COMPLEMENTARITY OF SCIENCE AND TECHNOLOGY

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1. INTRODUCTION

When the Ebola virus erupted in Zaire in 1995, it caused great local damage. However, the outbreak did not get to be classified as a major threat, at least in part because of a line of analysis that was drawn from the emerging field of "Darwinian medicine." For some time, leading exponents of that field (see Nesse, 1994; Bull, 1994; and Edwald, 1994) had been arguing that a pathogen can survive in a population only if it can easily transmit its progeny from one host to another. One way to do this is to take a long time to disable a human host; that gives the host time to come into contact with other potential victims. But Ebola virus kills usually in less than one week. Another way is to survive for a long time outside the human body, so that the pathogen can wait for new hosts to find it. But Ebola strains are quickly destroyed by sunlight. It was considerations such as this that contributed to the fact that the Ebola virus outbreak was not being classified as a major threat.

Darwinian medicine is a way to understand diseases in terms of natural selection rather than just as a technique for determining which symptoms to treat and which to ignore (see Nesse and Williams, 1994). It is a program aimed at turning the tables on harmful microbes, based on the proposition that, since they evolve much more quickly than humans do, it might be possible to harness their evolutionary power to human advantage. Darwinian medicine is also a way of exhibiting how disease-causing genes that persist in a population are often selected for, not against, in the long run—a phenomenon exemplified by sickle-cell anemia, a hereditary disease. People with two copies of the sickle-cell gene often die, but people with just one copy turn out to be able to resist the protozoans that cause malaria better than people with no copies of the gene at all. A rather brutal display of how evolution tallies costs and benefits lurks under the surface here: in malaria-plagued regions, carriers of two copies of the gene are generally more than made up for by the offspring left by disease-resistant kin.

Applications of Darwinian medicine appear to be on the increase in all directions. But is Darwinian medicine science, technology, or both? The field is manifestly pursued for scientific as much as for technological reasons. Darwinian medicine is not the only hybrid of this sort. Similar stories abound in all the advanced fields of technology—materials science, information technology, nanotechnology, and so forth. In all these, primarily non-epistemic goals share center stage with characteristically scientific aspirations to find out what the natural world is like, why it is the way it is, and even how one comes to accept and reject hypotheses about it. Indeed, in much of contemporary technological activity, there is creative conceptual inquiry of the sort that frees the mind of attachment to specific models and doctrines and helps to develop more appropriate views of the natural world.

So science and technology now seem closer to each other than ever. The fact remains that science and technology continue to *feel* like different projects. Why?

Some practical and theoretical concerns make this issue relevant, in particular the following three. First, the noted proximity of science and technology tends to discourage viewing science as an autonomous line of human excellence, and this might have disastrous cultural consequences, especially in education. Second, many exemplars of contemporary science seem as removed as possible from technological concerns—*in spirit* if not at the procedural level. (Cosmology, fueled so intensely by contemplative ideals, is a case in point.) Third, questions about the similarities and differences between science and technology are of interest to non-essentialist approaches to the study and classification of complex entities and properties.

Are there, then, any differences of philosophical interest between science and technology? I would like to begin with a sample of widely held opinions on the natures of technology and science. To that end, in the next section I survey two sets of views. The first is a characterization of *technological activity* by an influential technologist-philosopher, Robert E. McGinn. The second is a characterization of the *difference between science and technology* by an influential scientist-technologist, Lewis Wolpert.

II. CONVENTIONAL WISDOM

In "What Is Technology?," McGinn (1978) characterizes that form of human activity in terms of prominent aspects. He offers the following picture. (1) Technology is concerned with material, as opposed to ideational, outcomes. (2) Technologists make artifacts rather than just help something that is ordinarily done by nature. (3) Technology both expands human possibilities and enlarges the domain of human ends. (4) It is resource-based and resource-expending. (5) It is not exactly "applied science," but knowledge of resources and methods, how to do certain things. (6) The methods which technology uses range from trial and error to complex experimental techniques. (7) Economic, political, cultural, and ideological considerations enter into technological decisions; in turn they are conditioned by technological change, and technological activity both reflects and alters its context in any given stage of development.

Judging from McGinn’s characterization, technology seems to include everything that is dear to the scientific project. Only item (1), focusing as it does on an allegedly peculiar *goal* of technology, has clear differentiating possibilities. Even there, however, McGinn's wording is problematic, because it appeals to a distinction between material and ideational outcomes that looks misguided. (Think of the expanding information technologies of our age.) Items (2) and (5) have a presence in public discussions of technology, but they are unconvincing as characterizing features. As stated, (2) seems to place animal breeding outside the technological domain, at least if Darwinian selection is regarded as a general form of animal breeding done by nature. As for (5), there seem to be no methods which are used in science but not in technology, or the other way around. Actual science can be as methodologically opportunistic and dirty as technology (see Galison, 1997). As for the remaining items on the list, their lack of differentiating weight seems plain.

One could conceivably help (1) by modifying it a little. Especially in fundamental science, such goals as just finding out about the world tend to function as intrinsic values. However, the same could be said of many manifestly "technological" developments (nanotechnology, for instance). And let us not forget that modern science itself began as a very mixed pursuit of philosophical and theologico-technological ideals, especially at places like London's Royal Society (see Shapin, 1996).

The proposed characterization would thus seem to leave science as a mere variety of technology. But can this be correct? Lewis Wolpert (1993) does not think so. In his view, the two projects can be told apart by looking at their respective goals, methods, social context, and styles of understanding.

Openness figures prominently in his list among the characteristic features of science, along with allowance for controversy and public access to knowledge. Technology, by contrast, he presents as a style of thought that promotes secrecy and thrives in recipes and opaque (pre-scientific) procedures. This story may flatter scientists, but is it borne out by the facts? It does not seem so. Secrecy and opacity are far from uncommon in science. Virtually every one of the group-centered searches for new elementary particles has turned out to involve secrecy at some key level. Something similar can be said about the recipe aspect of technology. As for opaqueness, all the contemporary natural sciences rest on principles that cry out for additional explanation. Scientists may wonder more readily than technologists about the roots and meaning of their foundational principles, but the difference is one of only moderate degree.

Another feature Wolpert highlights is the practical orientation of technology. The latter, he notes, does not serve pure knowledge; whereas, for the inventor, the main reward is money, for the scientist it is intellectual esteem. This however also seems excessive. Technological enterprises tend to have greedy business as a major motivation, but not always—take the varied fields of medical technology.

Interdisciplinary and social context provide Wolpert with another angle. Here he makes the old point that, whereas technology has not always been dependent on scientific knowledge, science by contrast has almost always been heavily dependent on available technology. But how true is this of the present situation? The two forms of activity are now at least equally interdependent on one another. Wolpert also highlights the increasingly complex relationship between technology and industrial success in modern societies—a feature attested by Southeast Asia in the nineties, for example. But, again, the contemporary differentiating force of this is doubtful. If not in centuries past, science now has as large and complex a context as technology, including those contexts centered on governmental foundations and democratic choices.

So the proposed first-order differentiations in terms of methods, goals, and context do not seem to help very much. Could a contrast in terms of modes of *understanding* do a better job? Wolpert underscores the fact that scientific understanding was completely unnecessary for either the invention of the wheel or the appreciation of its usefulness. He also sees technology thriving in *ad hoc* hypotheses and conjectures directed at practical ends and not at understanding. But, again, none of this helps. Few are now willing to link appreciation of the scientific usefulness of a key theoretical principle to a deep understanding of it. (Think of the principles of general relativity or quantum mechanics.) Nor can one easily deny that theoretical principles are routinely left dangling as postulates at the highest levels of science, or that some major current scientific disciplines indulge in cheerful simplifications in order to render their descriptions coherent with larger bodies of knowledge, effectively calculable and so on. Probably few developments better illustrate this than the harmony achieved between special relativity and quantum non-locality in standard quantum field theories; there, agreement is secured from the start by imposing the "right values" on all the key commutation relations. This is not to say that this situation is scientifically desirable, let alone correct. The point is merely a factual one.

None of the practical—"technological"—turns highlighted by Wolpert are, by themselves, at odds with the pursuit of scientific truth (such as it is in actual scientific practice). All the behavioral traits glossed over fail to differentiate between science and technology. We can thus draw a first conclusion from the previous considerations. Easy characterizations of either science or technology fail to convince.

That said, Wolpert's focus on *understanding* may have a point, for its pursuit does seem differently set in science and technology. Technology is generally less engaged than science with the construction of broad rational pictures of the world. If this is so, however, the relevant variation will probably have to be sought at the level of contexts of inquiry, motivation, and history. Before plunging into such deeper waters, however, let us explore an obvious (and popular) reaction to the difficulty we have discovered of distinguishing between science and technology—namely, the subsumption of science into technology.

III. DENYING THE DIFFERENCE IN FAVOR OF TECHNOLOGY

One reaction invited by the negative conclusions reached in the previous section is to see science as a form of technological activity. John Dewey (1925, whose ontology I will otherwise salute in the last section) encouraged this kind of reaction through his celebrated view of scientific theories and concepts as technological artifacts. He saw technology as something that was both historically prior to science and functionally inclusive of it. Dewey's recommendation can be pushed in several directions, particularly the following two. It can be worked out into a characterization in which everything that is both purposeful and rational ends up being "technological." The resulting picture of human activity would then merely blur differences by stipulation and thus lack interest. More daringly, Dewey's insight can be pushed in the direction of full-blooded pantechnologism.

The Pantechnologist Temptation:

We can savor the appeal of pantechnologism by entertaining some plausible argumentative lines in its favor. Consider Dewey's intimation that scientific views and reasons are themselves technological phenomena— ultimately the products of social individuals working within technological parameters and subject to technological forces. One can interpret this as an invitation to become aware that "rational" entities, like reasons, arguments, and theories, are not primarily scientific entities but technological institutions. If so, the elements of scientific discourse would primarily require technological accounts rather than scientific-philosophic ones, and to treat scientific elements in non-technological terms would be to misunderstand their nature and to go for incomplete accounts which would lack credibility and accuracy.

This can be supplemented with a parallel argument to the effect that merely internal philosophies of science are hopelessly naive—that whatever scientists maintain, they ultimately hold the views they do, not because of the *reasons* they actually give, but because of factors which are part of the social and technological context in which they work. Can the scientific phenomenon be like that? It is not hard to recall some cases from the historical record in support of such a view. Consider, for example, the issue of predictability in classical astronomy. Orbiting Newtonian systems are clearly stable only when the acting force is strictly of the $1/r^2$ form. As gradually became clear in the 18th and 19th centuries, however, in actual systems perturbations easily spoil linearity. Planetary motion in the solar system, for example, lends itself to representation by means of purely periodic functions. But not all is the color of roses. In the 1890s, Poincaré (1892) famously shocked the establishment by showing that the relevant series generally diverge. He was right. Newtonian systems are a great deal less predictable than was once comfortably assumed. My point in telling this story is that technological explanations of facts about strategies of accommodation to available technology are sometimes relevant to the understanding of science.

But are the above pantechnologist arguments sound as general arguments? Can one establish so easily that accounts of scientific practice which do not pay proper attention to technological factors are *necessarily* inaccurate, because they ignore the actual constraints that produced the phenomena they aim to understand?

I do not think so. The "Deweyan" lines of reasoning are species of notorious externalist ploys in both the history of philosophy and the history and sociology of science (see Gracia, 1992). As such, they fail to convince. Although technological accounts of science can further our understanding of science, the fact remains that specifically scientific relevance and interest continue to be focused on existing scientific *knowledge* and on specific scientific *reasons* appropriate to claims about scientific development. In this regard, pantechnologist arguments are not of scientific or philosophical interest as such—unless of course science is conventionally construed in instrumentalist terms from the start, which would beg the question. Consider again the case concerning linearity and predictability. There is little question that, throughout the 19th century, many individual scientists deceived themselves about the scope of some of their linear models, and this certainly calls for an explanation of facts about strategies of accommodation to available technology. Note, however, how such an explanation leaves out all the important questions about reasons unanswered. The phenomenon of self-deception that took place is not automatically of interest as an answer to the question about *scientific* reasons and propriety. If all the pantechnologist has here is an engaging causal account of the episode, that does not, by itself, explain whether the scientists concerned were right in believing their models. It does not explain either why they took them seriously (if they did so). The technological context of the expression of a view is one thing; the view itself is quite another.

Admitting that scientific views and scientific phenomena are the result of technological forces does not commit one to granting scientific accounts a role secondary to technological ones, or even to regarding technological accounts as being on a par with scientific ones. The suggested pantechnologist accounts are inconclusive from the perspective of scientific rationality. One major problem with the pantechnologist turn is the questionable assumption that if technological context sanctions a view or a method, then scientists immersed in that context will follow suit. But this is simply not true in general, for scientists frequently challenge the views embodied in their received technologies. They sometimes take their views from ongoing technologies and sometimes not. At least in the mature sciences, *holding a view sanctioned by technology always has to do with the scientific merits that the technology employed embodies*. (Scientists are not always successful in this regard, but that is something else.)

None of this is to deny that there is technological interest in the phenomenon of science. But social and technological accounts, although useful and often necessary for understanding scientific developments, do not seem to be essential to it. Science is not merely an aspect of technology—at least not by force of principle.

IV. NON-ESSENTIALIST DIFFERENTIATION

How different then, is science from technology? As suggested earlier, differentiation has not always been regarded as something obvious or desirable within mainstream science. Many champions of early science (conspicuously Francis Bacon, but also Descartes, Newton, Boyle, and many others), regarded the improvement of the human mind and the improvement of the human lot as the same thing. And, at least until the 18th century, many of the best scientists conceived of scientific success in terms that sound like those of some religious technology.

What, then, are the present differences between science and technology, if any? To answer this question, it seems useful to try to further a bit McGinn's focus on goals and Wolpert's focus on selection criteria, particularly by bringing into the picture such aspects as differential emphasis and history.

Differential Emphasis:

Although very similar sets of goals and selection criteria underpin the practices of science and technology today, the values or weights attached to those common elements manifestly differ in the two forms of activity. In technology, success criteria generally emphasize the satisfaction of wants and needs that are largely non-epistemic. In science, by contrast, success criteria generally emphasize the satisfaction of such eminently epistemic needs as justification and truth. What tells present science and technology apart, it seems, is not a set of distinguishing characteristics, but differing valuational distributions over otherwise common characteristics. We can try to picture the envisioned differential distributions by concentrating on some well-recognized dimensions of both science and technology.

Munson's (1981) study of the nature of medicine provides us here with a tenable first approximation in terms of (a) internal goals, (b) internal criteria of success, and (c) ethical standards regulating the disciplines. Applying his approach to the case of science and technology, we get valuational differentiations along the following lines:

(a) *Goals*: One primary internal aim of science is the acquisition of knowledge and understanding of the world. Rarely, if ever, does a technology have that as its *primary* aim. Knowledge is always part of the project, of course, but the basic internal aim is generally something else. In medicine, for example, it is to promote the health of people—knowledge and understanding of diseases being generally oriented toward disease prevention and treatment.

(b) *Criteria*: To the extent that science is successful only if it achieves something worth calling "true" or "approximately true knowledge," science is epistemically more ambitious than technology. Technological disciplines can be (and usually are) satisfied with much less.

(c) *Ethics*: Gravitating around epistemic values, the ethics of science stresses maxims of a peculiarly philosophical kind. For example, it gives great methodological importance to honest reports of the results of inquiry. This is crucial to the success of science as a truth-seeking and truth-checking endeavor that has learned to prize cooperative effort. Honest reports are also methodologically important in technology, but there direct honesty competes with other values more readily than in science. In the practice of medicine, for example, lying to a patient or to an insurance company seems conceivably acceptable in some circumstances (as long as it is done for the sake of promoting the patient's health).

These differences are matters of moderate degree or emphasis only. They lead to a view of science and technology in which both forms of activity function as knowledge seeking enterprises, and both connect with other (arguably all other) human needs. As pointed out, however, common concerns like the search for comprehensive descriptions of large domains, or telling the truth, differ in centrality in the two enterprises. That is the sense in which different prototypical valuational matrices characterize science and technology. Scientific disciplines and technological disciplines simply tend to cluster around different valuational cores. Many (arguably most) disciplines, however, are not prototypical in this sense but are hybrids.

This way of looking at the situation, I suggest, helps us see contemporary science and technology as contingently autonomous lines of human flourishing, with different areas of human concern being encouraged or discouraged in relation to the various ongoing valuational cores. Foundational science is more dominated by contemplative ideals than ordinary technology; the latter is more dominated by ideals of prediction and control than science. As a parallel outcome, the profiles of *understanding* vary accordingly in the two enterprises, with different standards of satisfaction generally prevailing in each project—even at the local level. For instance, lack of internal coherence and compatibility with the best knowledge from other areas is much more of a concern in fundamental science than in technology. But, again, it is all a matter of moderate degree.

Historicity:

The contrasting distributions of valuational weights on which I am focusing have neither an a priori nor a fixed status. Accordingly, it would be both unwarranted and pointless to imagine the highlighted differences between current science and technology (intellectual and otherwise) as something fixed. In principle, every possible level of future convergence and divergence seems conceivable as growing out of the present.

This brings my analysis into what is perhaps one of the most insightful aspects of Dewey's philosophy, namely, his conception of the world as something open to change by human activity at all levels. My approach here agrees with Dewey's rejection of the metaphysics of objects whose meanings are fixed for all time by nature, by God, or even by human activity. As Dewey insisted, all objects, including individual human institutions, are in continual flux as they participate in transactions with their physical and intellectual environments. If this is so, questions about the connections between science and technology can only have historical answers. Of course, one can always reorganize the history of science or technology to make some features stand out, to promote those features as norms, and then to urge their projection into the future. However, one should not then deceive oneself into thinking that, at long last, one has got an essential point about science or technology (see Fine, 1989).

From the Deweyan perspective that I am endorsing, science and technology both take their place in an organic realm in which the perceived ends of objects, individuals, and events may be used as the means to further development in all directions. Contemporary technology and science differ without the backing of an underlying dichotomy. They have been rationally led to a state of profound complementary—being now more interdependent than ever before—although they continue to gravitate around different intellectual prototypes.

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