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Reflections On Science And Technoscience

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Reflections on science and technoscience

Hugh LACEY



ABSTRACT

Technoscientific research, a kind of scientific research conducted within the decontextualized approach (DA), uses advanced technology to produce instruments, experimental objects, and new objects and structures, that enable us to gain knowledge of states of affairs of novel domains, especially knowledge about new possibilities of what we can do and make, with the horizons of practical, industrial, medical or military innovation, and economic growth and competition, never far removed from view. The legitimacy of technoscientific innovations can be appraised only in the course of considering fully what sorts of objects technoscientific objects are: objects that embody scientific knowledge confirmed within DA; physical/chemical/biological objects, realizations of possibilities discovered in research conducted within DA, brought to realization by means of technical/experimental/instrumental interventions; and components of social/ecological systems, objects that embody the values of technological progress and (most of them) values of capital and the market. What technoscientific objects are – their powers, tendencies, sources of their being, effects on human beings and social/economic systems, how they differ from non technoscientific objects – cannot be grasped from technoscientific inquiry alone; scientific inquiry that is not reducible to that conducted within DA is also needed. The knowledge that underlies and explains the efficacy of technoscientific objects is never sufficient to grasp what sorts of object they are and could become. Science cannot be reduced to technoscience.

KEYWORDS • Technoscience. Science. Decontextualized approach. Technological progress. Values.

1 TWO IMAGES OF SCIENTIFIC RESEARCH

1.1 TECHNOSCIENCE

Research on objects and happenings at the nanoscale exemplifies a widely held image of scientific research. In it, the most advanced technology is used to produce instruments, experimental objects, and new objects and structures, that enable us to gain knowledge of events and states of affairs of a novel domain (the very small), especially knowledge about new possibilities of what we can do and make, with the horizons of practical, industrial, medical or military innovation, and economic growth and competition, not far removed from view. Knowledge is gained. The research is not just to

produce technological innovations. Sometimes it aims to gain the fundamental theoretical knowledge that research aiming immediately for practical innovations might depend on; sometimes to create instruments (themselves technological innovations) that will enable knowledge to be gained in new areas; and sometimes – according to Nordmann, 2012, characteristically of technoscientific research – to demonstrate that a particular effect can be produced by appropriate manipulation of objects and instruments. Although the science and technology can be thought of separately, the technology occupies a place of high salience in the conduct of the research. It is indispensable for making the instruments needed for observation and manipulation of the objects being investigated, and what can be achieved with it often determines the priorities of investigation. Sometimes the technology creates the objects investigated; and sometimes technological (medical, or agricultural) innovation is the immediate goal of the research.

This image of scientific research projects that the cutting edge of science is that which exploits the technological contribution to research, and which directly or indirectly furthers human powers to intervene into and control the world. This is what I call technoscience. In it, there is a distinction but not a concrete separation between science and technology, between, e.g., coming to know what is possible to observe, make, bring about and control at the nanoscale and the possible consequences of exercising such control at the level of everyday objects, and applying this knowledge to inform practical projects. This is not to reduce science to technoscience, or to deny that there is a shifting dynamic interaction between science and technology. It just points to the omnipresence of technology in all aspects of a certain body of scientific research, so much so that sometimes it may appear arbitrary to attempt to distinguish what is the science from what is the technology.¹

¹ Most of what is observed in nanoscientific research is generated by interaction with the instruments of observation or manipulation. Nanoscience doesn't fit well with the image of science aiming to grasp nature (natural objects) as it is independently of its relationship with human beings. Many of the objects of technoscientific research are not natural objects as these have traditionally been thought of. To use an example outside of nanoscience, a transgenic plant is not a natural object; it does not exist in nature and it is not produced by the "natural" interactions of plants that do exist in nature. Although its processes of growth, maturation etc., may be understood in basically the same way as any biological organism, it exists only in virtue of technological intervention. That is why a transgenic seed, but not a "natural" seed, may be the bearer of intellectual property rights, and why it may have distinctive social/ecological effects. Furthermore, although it is important to maintain the distinction between knowledge of the possibilities of transgenic technology and using this knowledge to inform farming practices, it is difficult to see why gaining this knowledge would be a priority or have any interest apart from the prospect of using it in practice. Effectively, this is knowledge of what it is possible for us to do by interacting in technological ways with natural objects. It does not expand our knowledge either of "nature", or the possibilities open to other modes of interaction with nature, e.g., those that maintain sustainability or better accord with social justice.

For me, “technoscience” is a broadly descriptive term, not a deep theoretical term or even a very precise one.² Nevertheless, it is worth using because nowadays powerful social/economic/political forces emphasize the value of technoscience, largely to the exclusion of other forms of science (see §5). While science is not reducible to technoscience, these forces would have technoscience displace other forms of science, so that – as a social phenomenon – science becomes effectively identified with technoscience, and scientific methodology becomes identified with the methodologies that it deploys. Hence, today it is widely taken for granted that technoscientific research projects are valuable, so long as the experts tell us so, and that it is worth pursuing in whatever directions are opened up by new instruments and techniques; moreover, it is legitimate to pursue this research and, only after innovative possibilities have been discovered, to ask what to do with them. Typically, of course, corporate (or military) funders of research want to implement innovative possibilities with little delay, and take for granted that this is legitimate. Generally questions about how innovations might be used to address issues of importance to poor people follow only later; and then usually ignoring that technoscientific objects are not only physical/chemical/biological objects, but also socioeconomic objects whose uses are constrained by regimes of intellectual property rights, which often entail that they can play little or no role of significance in practices that serve the interests of the poor.

1.2 ECOLOGICALLY ORIENTED RESEARCH

Technoscience does not provide the only image of science. Another image is exemplified in an article published in *Nature*, “Genetic diversity and disease control in rice” (Zhu *et al.*, 2000). Zhu and his colleagues aimed to deal with a fungus infection that affected rice crops over a large region of China in the 1990s and that caused massive crop losses. These crops, planted according to the “conventional” green revolution agricultural model, were of hybrid varieties grown in monocultures, and so readily susceptible to the spread of disease, for which the model provided principally the solution of using petrochemical-based herbicides, pesticides, fungicides etc. Technoscience promised a transgenic solution to the fungus infestation and dependence on fungicides, but the research had not even begun. This “solution” would be available, if at all, only years into the future and after enormous expenditure. Zhu’s research, which was con-

² My use of “technoscience” is more encompassing than that of Echeverría: “(...) in technoscience (contrary to what happens in traditional science) scientific knowledge is not an end in itself, but just an instrument to obtain social, political, economic or military ends” (Echeverría, 2005, p. 301; cf. Echeverría, 2003, where a more complex analysis can be found). I am unsure, however, about the proposal being explored by other contributors to this Special Issue that the ontology of technoscientific objects is distinctive (Bensuade-Vincent *et al.* 2011; Nordmann, 2012).

ducted on a very large scale, drew upon the fact that the fungus afflicting the rice crops is spread by wind. The idea was to plant two different varieties of rice in alternate rows, one (more high yielding) susceptible to the fungus, the other (with lesser yields) not susceptible. The second row provides a barrier, inhibiting the spread of the fungus. Within two years, the fungus had almost disappeared; crops overall had much bigger yields, and fungicide use was drastically reduced. The outcome was better for the farmers' (not agribusiness's) profits and for the environment.

An editorial commentator in *Nature*, after observing that long ago Darwin was aware that mixed cropping (of wheat) is more productive than monocultures, asked: "why is the mixed approach not widely used?". He answered with the rhetorical question: "is it just too simple, not making enough use of high technology?", and continued:

variety mixtures may not provide all the answers to the problems of controlling diseases and producing stable yields in modern agriculture. But their performance so far in experimental situations merits their wider uptake. More research is needed to find the best packages for different purposes and to breed varieties specifically for use in mixtures. (...) Mixtures of species provide another layer of crop diversity, with half-forgotten advantages waiting to be exploited in contemporary approaches (Wolfe, 2000).

Why should much more research funding go to technoscientific innovations in agriculture than to this "simpler" kind of research that is soundly based on ecological principles?³ Or to research that is not only based on sound ecological principles, but also directed to furthering the embodiment of values of social justice? Elsewhere (Lacey, 2005a, where I have drawn much from Altieri, 1995), I have given a lot of attention to agroecology, where research is conducted simultaneously attentive to productivity, environmental sustainability, preservation of biodiversity, social health, and empowerment of rural communities. And agroecology fits into the goals of "social technology", where "social technology comprises products, techniques and/or replicable methodologies developed in the interaction with the community and that must represent effective solution in terms of social transformation" (RTS, 2010), for the sake of furthering the social inclusion of the marginalized (cf. Dagnino, 2010).

³ This case, and others, are discussed in Lacey, 2005a, chapter 10, section 1. While I was preparing this article, a report appeared in The New York Times weekly science section that there has been an increase in funding for studies of "integrated pest management" for small organic farms in USA (cf. Robbins, 2010).

2 INDUCTIVE UNCERTAINTY AND SCIENTIFIC CERTAINTY

Scientists are bodily, intentional agents, who interact with people and things (with specific natures, capacities, powers, and tendencies) in the course of their practice. Scientific knowledge and scientific theories are outcomes of this practice, with its various components: experimental, observational, measurement, mathematical, statistical, modeling, simulational, discursive, argumentative, technological etc. A good deal of scientific knowledge, unaccompanied by practical concerns about uncertainty, has immediate and manifest impact on action and social practices. A lot of philosophy of science in both rationalist and empiricist traditions ignores this, effectively treating it as irrelevant to epistemological concerns. Consequently, it has little to contribute to efforts to grasp technoscience, its possible trajectories, and the nature of technoscientific objects.

The central problem for mainstream philosophy of science has been how to confirm and disconfirm theories on the basis of available observational data (cf. Nordmann, 2012), a problem that (in turn) required attention to the nature of theories and how confirmation should be understood, and it has spawned countless proposed solutions. In much of mainstream philosophy of science, the theories discussed have been considered to be universal in scope, typically involving some terms with no application to observable phenomena and mathematical in character. Thus, confirmation could never avoid uncertainty. This is not just a logical point, for the history of science seems to display a sequence of once “accepted” theories becoming replaced by successors, and there is no reason to hold that currently “accepted” universal theories will not go the same way. This lies behind Popper’s view that falsifiability is the key mark of a scientific theory, and that probing scientific research should be designed with a view towards attempting to falsify theories. Oddly enough, in this tradition of philosophy of science, there is little discussion of experiment, except as a source of observational data and thus as having a key role in adjudicating between competing theories. Popper, like the logical positivists that he criticized, never (to my knowledge) discussed experiment as a practical activity, and never discussed applied science at all, as if successes of applications are irrelevant to the epistemology of science. Popper never discussed why theories, which have no far resisted falsification, are able to inform applications successfully.

It is true that certainty or necessity (in the senses of Descartes or Aristotle or Hume) is not obtainable in scientific – systematic empirical – inquiry. It is always logically possible that future research may lead to the rejection of even the best confirmed result. However, there is a practical kind of certainty that is obtainable – this is what is usually meant when scientists speak of scientific certainty. Sometimes there is good

reason to expect that future research will not lead to the rejection of a particular result: when, after time, argument, responding to criticisms, repeated experimental tests, no one can suggest a further experimental (or other empirical) project that might make a difference, so that all relevant research has been conducted and only general logical/inductive doubts remain. When a result is accepted with scientific certainty it is part of the established stock of scientific knowledge and can be counted on to inform applications reliably.

A universal theory is never accepted with scientific certainty. Popper is right that potentially falsifying situations can always be described that have not been put to empirical test – the uncertainty connected with theories is more than merely logical. There is no reason to be confident that testing a theory in a new context will not lead to its falsification, and the history of science leads us to anticipate that even a theory that has survived many tests will eventually succumb to falsification. Universal theories do not belong to the stock of established scientific knowledge. However, a universal theory may be accepted as the most comprehensive non-falsified theory available, the theory to be surpassed in the quest for a general theory of the universe and so the one to be subjected to rigorous empirical testing by new kinds of experimental phenomena, or as an instrument for the discovery of phenomena of relevance for practical application.

Nevertheless, that a theory T provides understanding (adequate descriptions, explanations, predictions, anticipations of possibilities) of a specified domain of phenomena D – T of D – may be accepted with scientific certainty. T of D may be included in the stock of established scientific knowledge, the body of claims that need no further testing, concerning which there remain only general logical/inductive doubts. Subsequent falsification of T , when it fails to provide understanding in new domains of phenomena, frequently leaves the scientific certainty of T of D intact.⁴ T is accepted with scientific certainty of D if and only if it manifests the cognitive values to a high degree, according to the most rigorous standards of appraisal (cf. Lacey, 1999, p. 62-6), of a domain of phenomena. Countless successful applications have been informed by the knowledge expressed in theories accepted with scientific certainty of relevant domains, and this knowledge can explain why the applications are efficacious. Theories become

⁴ Newton's theory is accepted with scientific certainty of the domains of projectile motion and motions in the realm of most of the planets – as are numerous results, e.g., of standard molecular chemistry, solid state physics, and viral causes of some diseases. Newton's theory has been displaced as the general theory for research in domains that mainly became open to research in the late 19th and 20th centuries. That does not mean that Newton's theory of the stated domains has been falsified; indeed it continues to inform reliably many practical tasks. The scientific certainty of T of D is compatible with T_1 of D also being scientifically certain (where T_1 is a successor universal theory to T); and if T_1 provides no greater empirical adequacy pertaining to D (even if it has greater explanatory power), T will still suffice to inform practical projects where the phenomena of D are relevant.

falsified, but that they hold of certain domains of phenomena may remain practically-speaking certain, and this practical certainty is reinforced by the success of applications informed by theories accepted with scientific certainty of relevant domains of phenomena. It is true that the problem of induction remains, but practical agents think of themselves interacting with things (that have natures, powers etc.). The problem of induction is not a problem that practical agents, including the proponents of technoscience, feel the need to confront.

I have distinguished between “accepting a claim with scientific certainty” and “accepting a theory as providing the best framework for ongoing research”.⁵ Another sense of “accepting a claim” is also important, what I call “endorsing a claim”. To endorse a claim is to judge, after considering the consequences of its being false and their ethical salience, that the evidence supporting it is sufficiently strong to legitimate acting in ways informed by it (cf. Lacey, 2005b, 2011b). The efficacy of technoscientific innovations can normally be explained by results accepted with scientific certainty, but rarely can such certainty be obtained in the context of investigating the risks and uncertainties of technoscientific innovations. Ethical value judgments play an essential role in making endorsements; endorsed claims do not manifest the cognitive values to a high enough degree according to the most rigorous standards of appraisal (for methodological implications, cf. Lacey, 2011b).

3 IS IT DESIRABLE THAT TECHNOSCIENTIFIC ADVANCES CONTINUE?

It is not inevitable that technoscientific advance will continue to transform the lives of virtually everyone. Whether it will or not, and in what directions, depends on what research is pursued successfully, the choices that scientists make, the forms of education that scientific institutions foster, whether the effects of implementing technoscientific innovations are compatible with natural and social sustainability, the interests of dominant economic and political institutions, and the values embodied in them. Of course, given that economic growth is the prioritized value of most of these institutions, and that they provide the material and social conditions for technoscientific research but not (to a comparable degree) for other approaches to science, it is likely (at least for the foreseeable future) that technoscientific advance will continue, that innovations will reflect the interests of the dominant institutions, and that the predominant tendency among scientists will remain that of choosing to engage in research that serves this advance.

⁵ This distinction can be recast perspicuously in terms of model-theoretic approaches to the nature of theories.

Is it desirable that technoscientific advance continue – in general and, specifically (see §5), as subordinated to the interests of economic growth and corporate profits? Are developments of, e.g., transgenics or nanotechnology or neurosciences generally desirable?

When I ask these questions, many people respond: “aren’t these developments established realities? Like it or not, they are here to stay”. It’s idle to ask about their desirability in general, for a negative answer could have no practical impact. Moreover, in any case, we can’t know antecedently what the uses of technoscientific innovations might be. Many valuable uses that might emerge can be imagined, as well as others that haven’t yet been thought of. How could the case be made that curtailing their discovery might be desirable? Wouldn’t it be more appropriate to ask: how can these developments be managed so as to maximize their benefits for as wide a range of people as possible, to minimize the possible harm that they may cause, and to put them to use for dealing with the problems and needs of poor people? These people assume that there are developments to be found that can be used to serve the interests of the poor. The research is going to be done – so many scientists have been trained to pursue technoscientific advances, and they are not going to put that training aside. Then, rather than taking the question stated above seriously, the focus should be put on finding uses that fit with the values of justice, or the right for everyone to benefit from the advances of science.⁶

Certainly, actually implemented innovations should be managed in accordance with regulations designed so as to minimize possible harm; and, if they can serve to deal with the needs of poor people, then they should be developed in appropriate ways to do so. However, e.g., that the widespread use of transgenics is an established fact, and thoroughly integrated into many national and international agricultural and food policies, does not mean that there may not be better alternatives – alternatives with comparable or greater benefits, comparable or lesser risks, and better suited to respond to the needs of poor peoples and to respect their interests and values.

It may well be idle to ask about the desirability of technoscientific advance in general, and I have no doubt that some technoscientific innovations are desirable in many areas. But, it is not idle to ask: in a given domain (e.g., agriculture), should technoscientific advances (e.g., transgenics) be prioritized rather than some alternatives (e.g., agroecology) that are not based on technoscientific innovation? Just as the widespread use of transgenics is an established fact in many, though not all, parts of

⁶ Article 15 of the International Covenant on Economic, Social and Cultural Rights requires states (among other bodies) to recognize the right of everyone to enjoy the benefits of scientific progress and its applications, and to conserve, develop, and diffuse science (AAAS, 2010).

the world, it is also a fact that there is plenty of disagreement about whether or not technoscience (biotechnology) is by itself an adequate source of farming methods that are sustainable and that provide food security for poor peoples. Recently, a growing number of publications, from different perspectives including reports from leading scientific and developmental bodies, have proposed that a variety of farming methods need to be developed, if the food and nutrition needs of everyone are to be met.⁷ Agroecology is often highlighted in them. Most of them do not firmly reject a role (perhaps a significant but a qualified one) for transgenics; and virtually all agree that the components of the variety (and how they might be distributed) remains to be settled by empirical inquiry. It may well be desirable to continue research on transgenics, but currently there is no unanimity that it should be the centerpiece of agricultural research, taking funding resources away from other approaches in which the use of technoscientific innovation is not of first importance.

Furthermore, I suggest that questions, like the one just raised in the case of agriculture about priority to be given research aiming for technoscientific advances, should be asked in connection with all practical domains and all technoscientific fields (see note 8). Technoscientific innovations are a product of scientific research, but the desirability or legitimacy of implementing them (or the presumption of it) does not follow from any scientific knowledge. What is, and is not, desirable in a particular practical domain is not a matter that can be settled by scientific research; at the same time, it cannot be responsibly determined without the input of appropriately designed scientific research that, we will see, cannot be limited to technoscientific research.

3.1 THE TRANSGENICS/AGROECOLOGY ISSUE

To get a reasonably concrete idea of what I have in mind, think a little bit more about the transgenics/agroecology case (cf. Lacey, 2005a, part 2). Transgenics are exemplary technoscientific objects. They are products of research on genetic recombination, focussed not on how genes combine and recombine in “nature” in the course of, e.g., sexually based reproduction, but on what recombinations we can bring about using an array of engineering interventions and on what characteristics we can cause plants to have by means of such interventions. Transgenics were introduced into agricultural practices by agribusiness corporations, drawing on research largely funded and oriented by these corporations, for the sake of serving their interest in gaining greater profits and control of the agricultural market. This research did not aim either to fur-

⁷ These publications include: Altieri *et al.*, 2012; De Schutter, 2010; Foresight, 2011; IAASTD, 2009; Pretty, 2008; Pretty *et al.*, 2006; Royal Society, 2009; Wise & Murphy, 2012; Wittman *et al.*, 2010; World Bank, 2008.

ther our understanding of genetic recombination or other fundamental biological processes, or to improve the food security of poor peoples; it concerned only how to insert desired genetic materials into the genomes of crop plants and to apply the results in agricultural practices of interest to the corporations. Transgenics were not introduced in accordance with answers to the following questions (Lacey, 2008a), and empirical investigations relevant to answering them:

- What agricultural methods – “conventional”, transgenic, organic, agro-ecological, biodynamic, subsistence etc. – and in what combinations and with what variations, could be sustainable and sufficiently productive, when accompanied by viable methods of distribution, to satisfy the food and nutrition needs of the whole world’s population in the foreseeable future?
- Are there alternatives with productive capacity comparable to, or greater than, that of transgenics? Alternatives that could satisfy food and nutrition needs in contexts where transgenics methods have little applicability? Not necessarily a single alternative, but a multiplicity of complementary, locally-specific alternatives, which include agroecology and which simultaneously are:
 - (a) highly productive of nutritive foods, environmentally sustainable and protective of biodiversity;
 - (b) more aligned with and strengthening of rural communities and the diversity of their aspirations with place and culture;
 - (c) capable of having an integral role in producing the food needed to feed the increasing world population; and
 - (d) particularly suited to ensure that rural populations in impoverished regions are well fed and nourished?⁸

4 WHY IS TECHNOSCIENTIFIC RESEARCH PRIORITIZED?

Why are these questions usually not asked? Why is technoscientific research widely prioritized (often apparently without awareness that there may be alternative approaches), so that the first questions asked tend to be, not the ones just posed, but

⁸ Generalizations and counterparts of these questions need to be stated for other domains of practice (cf. Lacey, 2008b). They are among the questions that need to be answered for the sake of appraising the value (desirability and ethical legitimacy) of implementing technoscientific innovations.

questions about what innovations are possible, generally in a research context where innovations of interest to corporations – or the military or hi-tech medical practitioners – are given primary attention? It is taken for granted, first, that technoscientific innovations are the key to improving, e.g., agricultural practices to make them more able to meet the food and nutrition needs of everyone in a world with an expanding population and limited arable land and, second, that uses of innovations for serving the needs of the poor can always be found and that technoscientific innovations are the key to addressing these needs (see §4.4). Then, later it is asked what needs the innovations at hand might be deployed to address (usually without input from the supposed beneficiaries, prior analysis of their overall needs, and the causes that maintain them – Lacey, 2005a, chapter 8, section 3); but, even then the same kind of attention is not given to them as given to producing the innovations. Moreover, why are scientific research and educational institutions structured and funded so as to facilitate this way of conducting research?

The “why?” in these questions can mean either “how to explain?” or “how to justify ethically and rationally?”. I think that these phenomena are easily explained; but that does not imply they are ethically justified – and that there may not be good reasons to challenge them.

4.1 THE AIMS OF SCIENCE

How should we think of science? I propose, in summary: science is systematic empirical inquiry aiming to gain knowledge and understanding of phenomena, of the means for efficaciously acting or intervening to change the course of events or to maintain environmental sustainability, and of what can be brought about by such interventions; and, where appropriate, to use this understanding to inform practical (including technological) projects. What phenomena? Natural phenomena, those pertinent to practical activities, technological phenomena, those generated in technoscientific experiments – and under what characterizations? What techniques of intervention? Those that will contribute to further scientific research, any ones that we happen to be able to develop, those that can be marshaled in service to dominant economic and military interests, those whose use is consistent with maintaining adequate resources for the use of future generations, those that could be utilized widely under democratic supervision, those that could have a role in “social technologies” (see §1.2)? What are the priorities?⁹ The two images of scientific research, sketched in §1, both fit into this

⁹ This expands my discussions of the aims of science elsewhere (Lacey, 1999, chapter 5; 2005a, chapter 3, section 2; 2012).

picture, while pointing to fundamentally different priorities. Science is also a social, historical phenomenon. Its modern tradition has been the bearer of specific values, which I have maintained elsewhere (cf. Lacey, 1999; 2005a) include impartiality,¹⁰ neutrality and autonomy, and its concrete forms are subject to dynamical change.

4.2 THE DECONTEXTUALIZED METHODOLOGICAL APPROACH

I have not built into the aims of science one feature that has strongly marked the whole tradition of modern science, i.e., that modern scientific research grants special privilege, virtually to the point of exclusivity, to a particular methodological approach. In general, I have argued elsewhere (cf. Lacey, 1999; 2005a), scientific research cannot be pursued unless (what I call) a methodological strategy is adopted, where the principal roles of a strategy are (1) to constrain the kinds of theories that may be entertained in a research project (the kinds of categories that may be used in theories, the class of possibilities that may be explored, the kinds of models, analogies and simulations to be deployed), and (2) to select the kinds of empirical data (and the descriptive categories to be used in observational reports) to be procured, reported and analyzed, and of what phenomena, so that theories may be appraised empirically.

Modern science has given privilege to strategies that are part of (what I call) the decontextualized approach (DA). Theories are constrained so that they are able to represent the underlying order of things – their underlying structures, the processes and interactions of them and their components,¹¹ and the laws governing them, and to represent phenomena as generated from the underlying order. The data selected are largely quantitative, obtained by means of interventions with measuring instruments, and often of phenomena in experimental spaces. Strategies that are part of DA dissociate the phenomena investigated from human, ecological and social context, from any links with ethical and social value.

Thus, e.g., the underlying bio-molecular structures of seeds are investigated in research on transgenics. That transgenics are also economic commodities, and that their being so may be an important source of ecological and social risks, is ignored.¹²

¹⁰ It conflicts with impartiality to misidentify endorsements (end of §2) with claims accepted with scientific certainty (cf. Lacey, 2011b).

¹¹ These may be influenced (where complexity and non-linearity are relevant) by interactions among the levels of organization of the phenomena and their underlying structures. When this is ignored in research practices, DA is reduced to what may be called the reductionist approach. Elsewhere (cf. Lacey, 2009c; 2012) I have referred to the decontextualized-reductionist approach (D-RA). In this article I leave aside issues connected with reductionism (cf. also Lacey, 2011a).

¹² For a more complete account of strategies of DA (of which there are many kinds, and new kinds are regularly introduced), see my account of “materialist strategies” in Lacey (1999, 2005a). I say that strategies of DA are given

But the latter (as well as the examples referred to in §1.2) may be investigated under strategies that are not reducible to those of DA, and sometimes scientific certainty (§2) is obtained in such investigation. Moreover, DA-research lacks the means to address the questions raised in §3.1, since they deal with matters where context is crucial. Science needs to extend beyond the limits of DA.

4.3 THE DECONTEXTUALIZED APPROACH AND THE VALUES OF TECHNOLOGICAL PROGRESS

Technoscientific research is conducted under strategies of DA. Before developing this point to obtain a fuller account of technoscience (in §5), I will consider the question: why, despite the limits just referred to, has the modern scientific tradition privileged DA – and ignored (downplayed or not acknowledged) that science can be fruitfully conducted under strategies that do not fit into DA? The remarkable fruitfulness of science conducted within DA, both in gaining understanding of phenomena and informing efficacious applications – is an integral part of the answer, but *per se* it explains only that DA research is conducted on a large scale, not that it is privileged in a way that downplays other approaches.

One answer draws upon the links of modern science with holding materialist metaphysics, the view that the world – or the “natural world” – can be fully grasped (in principle) within categories deployed in (current or future) strategies of DA. I will not discuss the limitations of this answer here (cf. Lacey, 2009a). Rather I will attend to another answer that has its historical roots in Bacon’s valuing of the “domination of nature”,¹³ specifically upon its developments into (what I call) the values of technological progress (V_{TP}). In summary, granting high ethical and social value to expanding the human capacity to control natural objects to bring about intended consequences, especially as embodied in technological innovations; to innovations that increase the penetration of technology ever more intrusively into ever more domains of human life; and to the definition of problems that permit scientifically informed technological

privilege. Certainly their role is integral to the self-understanding of modern science, and theories developed under these strategies (physical and chemical ones) have been considered exemplary in writings in the philosophy of science. However, other strategies have been used in modern science: in psychology, the social sciences, ecology and research on biological evolution – “adaptation to the environment” does not easily fit into DA, and terms used to explain particular cases of adaptation often include sensory ones. The privilege given DA has been connected with the idea that physics is the exemplary science, and the metaphysical view of physicalism and thus the commitment to physicalist reductionism (cf. Lacey, 2009a). Some recent writings in the philosophy of science have challenged whether or not physical models serve well for understanding the character of biological research, and increasingly some philosophers of science have been proposing that biology, rather than physics, should be taken as the starting point for reflection about methodology (e.g., Mitchell, 2009; cf. Lacey, 2011a).

¹³ Schwarz’s article in this Special Issue provides an analysis of Bacon’s views that can easily be fitted into (and, at the same time, enrich) my account here.

solutions. I have argued elsewhere that there are mutually reinforcing relations between adopting DA and holding V_{TP} .¹⁴ Then, we can explain the privilege in terms of these relations, the fruitfulness of DA-research, and the fact that V_{TP} are highly embodied in contemporary hegemonic social/economic/political institutions and widely expressed throughout the world.

Reference to the mutually reinforcing relations between adopting DA and holding V_{TP} contributes to explain the privilege given to research conducted under DA, (and also to explain the appeal of V_{TP} and the strength of its embodiment in contemporary institutions). This is not the same thing as taking the adoption of DA to be subordinated to the aim of furthering V_{TP} – although it is compatible with it, or with considering practical application or utility (furthering V_{TP}) to be the principal aim of science. Throughout the modern scientific tradition, the quests for gaining understanding and for practical utility, although related and not always easily separable, have usually been considered to be relatively independent, so that the trajectory of “basic” science is not regarded as subordinated to that of applied science. Its direction in a particular field may be immediately motivated by practical concerns (cf. Stokes, 1997); or successfully informing practical outcomes may be considered to be essential confirmation of scientific knowledge;¹⁵ or basic science may be conducted well away from the immediacies of practical interests. The mutually reinforcing relations permit a range of aims to be pursued by individual scientists and institutions. For some, very close contact with potential application is essential. For others, the aim of science is gaining understanding of phenomena and of the laws and structure of the universe, where this is considered a value *per se*, where application is merely an incidental consequence (a happy one, since it motivates the provision of conditions for research). For still others, gaining understanding in “basic” research can be expected to have eventual, long-term practical pay-off, though how and when cannot be anticipated – so that the value of gaining understanding need not be separated from (nor reduced to) that of utility.¹⁶

¹⁴ For details on all the contents of this paragraph, including V_{TP} , and the components of the mutually reinforcing relations, cf. Lacey, 2005a, chapter 1; 1999, chapter 6. On what it means to “hold” values, cf. Lacey, 1999, chapter 2; 2005a, chapter 3.

¹⁵ This is Bacon’s view; cf. Schwarz (2012) on Bacon’s view of the virtual inseparability of discovering and inventing. Martins (2010) discusses how Vico’s version of it has historically had great influence on thinking about technology and its relationship with science.

¹⁶ Reviewing a book, *The age of entanglement* (Gilder, 2009), Peter Galison observes that the theories of quantum mechanics had for over eighty years grappled with the phenomenon of quantum entanglement, and that this seemed to be a case of theorizing that was as far removed from imaginable applications as one could get. However, “Entanglement was here to stay: Bell’s inequality, powered by experiment, said so. What’s more, the oddness of entanglement makes a new kind of computing imaginable. Odd as it might seem, these foundational ideas of quantum mechanics have led governments, industries and militaries to explore how the entangled state of separated particles

4.4 JUSTIFYING GIVING PRIVILEGE TO RESEARCH CONDUCTED WITHIN THE DECONTEXTUALIZED APPROACH

Explaining the privilege given to adopting DA – if not to the point of exclusivity, at least to considering the strategies it encompasses to be exemplary of “sound science”¹⁷ – is not the same thing as justifying it. Justification, in the present context, depends on there being good reasons for holding V_{TP} . Where V_{TP} are widely held and deeply embodied in hegemonic social/economic/political institutions, including scientific ones, it is not likely that identifying good reasons for holding these values will be a concern of high priority, since that there are such good reasons will not be generally questioned (or regarded as relevant, see §3). Be that as it may, to contribute towards ethically justifying the privilege given to DA, it is not enough that V_{TP} be widely held. Furthermore, it is not enough that their being widely held can itself be explained in terms of further mutually reinforcing relations between them and the values of capital and the market ($V_{C\&M}$), values such as economic growth and gaining competitive advantage, that derive from the fact that today the institutions that embody $V_{C\&M}$ are the principal bearers of V_{TP} – unless, of course, there are good reasons to hold $V_{C\&M}$!

There would be good reasons for holding V_{TP} today if propositions like the following (Lacey, 2005a, chapter 1) were well confirmed:¹⁸

- (a) On-going technoscientific (technological) innovation expands human potential and provides benefits that can be made available to all people.

might accelerate computing to a staggering degree: instead of taking, say, a million steps to crack a secret password, the still-nascent quantum computer promises a solution in the square-root number of steps – in this case, a mere thousand steps. What had been for generations a story of theoretical malcontents now intrigues spooks and startups.” He concludes with the tease: “quantum physics lives” (Galison, 2009).

¹⁷ Standard risk analyses are conducted within DA (cf. Lacey, 2005a, chapter 9), or under reductionist strategies (cf. Mitchell, 2009), and claims that there are serious risks (or uncertainties) involved in implementing certain technoscientific innovations are often criticized for lacking the credentials of “sound science” (no doubt some of them do!), where deployment of DA (or D-R A, note 11) is taken to be integral to sound science. However, what “sound science” entails is contested – consider: “sound science is based on transparency, verifiability, and reproducibility (e.g. reporting of methods and data in sufficient detail, so that the resulting data and information could be confirmed independently), and on the accessibility of data (e.g. the availability of relevant, required data or information or, if requested and as appropriate, of sample material)” (CBD, 2010). This proposal requires neither that adopting DA be integral to sound science, nor that scientific certainty always be its outcome – sometimes sound science only provides grounds for endorsements (see end of §2). For details about standard risk analyses, and criticisms of them (including those connected with “sound science”), cf. Lacey, forthcoming b.

¹⁸ Cf. Lacey (1999, chapter 2), for my general views on holding values and its rational dependence, not on that they are actually highly embodied in predominant social institutions, but on presuppositions broadly open to empirical investigation. I take furthering general human well being to be the foundation of sound ethics.

For more discussion of V_{TP} and its presuppositions, cf. Lacey (2005a, chapter 3), and of the kind of research needed to test the presuppositions of V_{TP} and $V_{C\&M}$, cf. Lacey (2005a, chapter 11).

(b) Technoscientific solutions can be found for virtually all practical problems, in medicine, agriculture, communications, transportation, energy provision etc. – including those occasioned by the “side-effects” of technological implementations themselves, so that there are no risks of technological innovation that cannot be taken care of by means of additional technoscientific developments.

(c) For most of these problems there are only technoscientific solutions.

(d) V_{TP} represents a set of universal values; they are held by most people in the world today, at least by those who have reflexively endorsed their personal values following participation in informed critical dialogue; and they must be part of any viable value outlook today – there is no viable alternative.¹⁹

I consider (a)-(d) presuppositions of reasonably holding V_{TP} today. Unless one endorses them or closely related propositions, it is not reasonable to hold V_{TP} ; and, *ceteris paribus*, it would be practically inconsistent to endorse them but not hold V_{TP} . There are other viewpoints. Some may hold V_{TP} because of their contribution to furthering the $V_{C\&M}$ (especially economic growth); then endorsing the presuppositions of $V_{C\&M}$ (explicitly formulated in Lacey, 2005a, chapter 11) is crucial, and usually these include that economic growth is indispensable for furthering general human well-being,²⁰ and that there are no viable alternatives to neoliberal economic policies and practices. Together, if confirmed, (a)-(d) would provide strong support for the claim

¹⁹ Propositions like these are discussed at length throughout Martins (2010). Variations on them are integral to the rhetoric of advocating that public support be made available for technoscientific advances. We find them in advertisements, news programs, editorial comments, political campaign rhetoric, and in the statements of spokespersons of scientific institutions when they seek funds for their projects, e.g., stem-cell research, the human genome project, nanotechnology, and research and development of transgenics. Cf. Lacey (2005a, part 2), for documentation of the rhetoric in the transgenics case. Also, cf. Lacey (2009a, 2009b) for consideration of mutually reinforcing links between holding V_{TP} and the viewpoint of materialist metaphysics. Sound independent arguments for materialist metaphysics (if there were any) perhaps would enable reasons to be given for holding V_{TP} that do not rest on propositions like (a)-(d).

²⁰ For some others, post-humanists, human well being is not of primary concern, but rather the development of intelligence and its powers. These people may not endorse that there are technological solutions to all the identified social problems: there may be no solutions at all, e.g., to problems connected with global warming; indeed there may be no way for human life to continue on Earth – then, the singleminded pursuit of furthering V_{TP} (which itself involves the most sophisticated and distinctive uses of human intelligence) is crucial and urgent for the survival of terrestrial intelligent beings, even if that involves going elsewhere in the universe or if it implies profound technological penetration into the lives of most people. Of course, the post-humanist valuing of V_{TP} also has presuppositions that are open to empirical investigation. I will not engage with this view further (cf. Martins, 2010, part 3, for a detailed discussion and criticism).

that technoscientific innovation not only serves to further human well being, in principle, for everyone everywhere (a)-(c), but is indispensable for this end (d). That would appear to be a strong ground for holding V_{TP} , and hence for prioritizing research conducted within DA.

4.5 QUESTIONING THE PRIVILEGE GIVEN TO THE DECONTEXTUALIZED APPROACH

I say “appear to be a strong ground”, for there are serious ambiguities hidden in this line of reasoning.

(i) It can at most support prioritizing DA for research in some, but not all, fields. The conclusion depends on the empirical confirmation of (a)-(d), not just on “believing” them or endorsing them without regard to the available evidence; but these propositions cannot be investigated solely within DA: they are about socio-historical phenomena for which context is ineliminable. Adopting non-DA strategies is necessary for research that could confirm or disconfirm them – and any confirmation obtained would be subject to re-thinking and new research in the light of the changing historical record. Whatever justification there may be for whatever priority is given to DA, and in what fields, depends in part on the outcomes of research conducted under non-DA strategies.

(ii) V_{TP} are held as part of value outlooks that also contain other values, and they are socially embodied in institutions that also embody other social values. V_{TP} are interpreted differently, and they engender different actions and programs, in the light of what the other values may be. Under all interpretations they reinforce the adoption of DA strategies in scientific research, but the objects of research (and specific experimental and instrumental methods deployed) may vary with how V_{TP} functions alongside other values, e.g., economic growth or profits ($V_{C\&M}$) and environmental sustainability or worker/consumer safety or prioritizing health problems of poor people. The presuppositions of holding these other values also need to be empirically investigated under non-DA strategies. This means that a general argument for adopting DA does not suffice to justify specific research projects that are conducted in service of interests that embody $V_{C\&M}$.

(iii) The presuppositions of V_{TP} are widely asserted (see note 19) and aggressively taken to be obvious. The issue of whether or not they are well confirmed empirically is seldom raised in the mainstream, whose research projects almost exclusively are within DA. In (i) I affirmed that they can-

not be adequately tested within DA, because of the historicity of technological innovation and its social impact. In addition, testing (c), e.g., requires assessment of alternatives that are not fundamentally based on technological innovation, and that are informed by research, much of which is conducted under non-DA strategies; and testing (b) requires investigation of risks that implementations of technoscientific innovations occasion by virtue of their socioeconomic character and their long-term impact on ecological and social systems (cf. Lacey, 2005a, chapter 9; forthcoming b), risks that fall outside of the scope of standard risk assessments that are conducted within DA (see note 17). Regarding (c), the object of research of, e.g., agroecology (§1.2) is the agroecosystem, which cannot be reduced to its components and their underlying order, and its potential for enhancing simultaneously productivity, ecological sustainability, social health and local empowerment. Unless the claims of the potential of agroecology are adequately countered, and more generally the question stated in §3.1 addressed in systematic empirical research – and this cannot be done within DA alone –, there can be no empirical warrant for claims, e.g., that there are no suitable alternatives to using transgenics and, thus, that there are no viable alternative outside of the trajectory of V_{TP} . A similar point applies to the claim that using transgenics poses no serious risks that cannot be taken care of by further technoscientific developments.

One might put it, with a hint of paradox (cf. Lacey, 2009b), that in order to test presuppositions of justifying giving priority to research conducted under DA-strategies, research needs to be conducted under non-DA strategies.²¹ This research might – or might not! – provide evidence that disconfirms (c) and (b). The hint of paradox is present only where it is thought that (a)-(d) may be well established empirically, not when (a)-(d) are held dogmatically (or, shall we say, ideologically?).²² Where meth-

²¹ In the absence of the relevant research being conducted under non-DA strategies, there will be no scientific evidence that the alternatives proposed to practices based on technoscientific innovation are viable. But the absence of available scientific evidence for them does not imply that there is scientific evidence available that they are not viable. Either way, the relevant evidence has to be obtained in the course of conducting research under non-DA strategies. This should be kept in mind when technoscientific experts assert that there is no scientific evidence that there are serious, non manageable risks incurred by a specific technoscientific innovation.

²² Where they are asserted dogmatically, effectively that are being endorsed just because they serve as presuppositions of reasonably holding V_{TP} (or, more likely, because of their connection with presuppositions of holding V_{CRM}) – their role is ideological. This is an instance of deriving factual claims from values, a fallacy that Bacon warned about at the beginning of the modern scientific era.

odological pluralism is openly embraced, and research conducted that points towards the disconfirmation of (a)-(d), then the question of interest (without hint of paradox) becomes under what conditions, and in what fields, research conducted within DA is significant, and how research conducted under non-DA strategies may complement it. This allows that technoscientific innovation has an important place in addressing world problems and furthering human well being, while maintaining that the value of technoscientific innovations needs to be appraised case by case, in contexts where the possibility of alternatives, not fundamentally grounded in technoscience, is not dismissed without a fair empirical hearing.

Elsewhere (cf. Lacey, 2005a, part 2), attending to the transgenics/agroecology case, I have suggested that the preponderance of evidence may point to the disconfirmation of all of (a)-(d). Against (a), transgenics do not provide benefits for all farmers. Agroecology, e.g., is not based fundamentally on such technoscientific innovations as transgenics, which have their principal place in industrial agriculture and have little relevance for small-scale farming. Against (b), transgenics occasion risks, e.g., destruction of biodiversity and deepening food insecurity for many poor people that, because of their socioeconomic mechanisms, cannot be adequately redressed by new technoscientific innovations. And, against (c) and (d), there are alternatives – agroecology is an exemplary case – whose productive potential at least merits further and urgent exploration, since they are integral to projects of food sovereignty (cf. Lacey & Lacey, 2010; Wittman *et al.*, 2010).

5 SCIENCE AND TECHNOSCIENCE

In technoscience (partly repeating remarks in §1.1), the most advanced technology is used to produce instruments, experimental objects, and new objects and structures that enable us to gain knowledge of events and states of affairs of novel domains, especially knowledge about new possibilities of what we can do and make, with the horizons of practical, industrial, medical or military innovation, and economic growth and competition, not far removed from view. Even where technoscientific innovation is not the immediate objective of a research project, technoscientific products (and sometimes new innovations) – instruments for measurement, surrogates for observation and interventions, experimental apparatus, and computing devices with powerful calculational capacity for analyzing data – are needed for conducting the research, so that technoscientific innovation can be a by-product of creating the necessary conditions for conducting the research. The cutting edge of science becomes that which exploits the technological contribution to research, and which directly or indirectly furthers

our powers to intervene into and control the world,²³ so that V_{TP} are not only often furthered by the knowledge gained in technoscientific research, but also by the very conduct of the research itself.

Technoscientific research is conducted within DA. I have maintained that there are mutually reinforcing relations between adopting strategies of DA and holding V_{TP} , but this is compatible with research within DA being conducted, with no immediate concern for practical application or for expanding our capacities for control, according to agendas set by theoretical interests and the interest to expand our understanding of phenomena of the world. Even so, because of these relations, the horizon of practical application in service to V_{TP} is present, perhaps a very distant horizon (as it largely was until the middle of the 19th century). With technoscience what has changed is that the horizon has become much closer, and the cutting-edge agendas of research have become more and more responsive to practical concerns. Technoscience involves research conducted within DA, where the immediate agendas of research are heavily shaped by interests connected with V_{TP} . It is not that the possibility of research being conducted under DA for “purely” scientific/cognitive motives has been eliminated, but that its value has become secondary in mainstream scientific circles and the institutions that fund research, where gaining patents to the products of research has become highly valued. But it retains value: technoscientific research aiming to have immediate economic or other practical payoff typically cannot be conducted without being informed by background well confirmed fundamental theory, and/or by the availability of suitable instruments for manipulating materials. The research that produced transgenics, e.g., depended upon prior knowledge having been gained about the molecular structures of genomes; cures promised to follow stem-cell research depend upon fundamental understanding of cell development; nanotechnology became possible following the construction of instruments that enabled the manipulation of individual molecules. Consequently, technoscientific research that involves theoretical pursuits or novel instrument construction, and that is quite removed from the immediacies of product development, may be well funded (by government agencies and universities, generally not by corporations), sometimes because it is recognized as necessary for certain types of products to be developed, but sometimes with only the general confidence that eventually this research will lead to pay off. Either way, this research is considered to have value because of its contribution to furthering V_{TP} .

²³ The control valued by those who hold V_{TP} is the kind of control demonstrated in experimental manipulations and in efficaciously using technological objects. Another sense of control is involved where $V_{C\&M}$ are held, the control obtained when a product is appropriated to serve special interests, of corporations, the military, rich people etc. In technoscience both senses are pertinent (cf. Marcovich & Shinn, 2012, p. 46).

Technoscience intensifies, and brings to the forefront, a tendency that could always be entertained when research conducted within DA is prioritized.²⁴ This tendency is fueled by the way in which, at the present time, V_{TP} and $V_{C\&M}$ are dialectically intertwined. $V_{C\&M}$ is the primary bearer of V_{TP} today, and V_{TP} tends to be interpreted in the light of the interests that reflect $V_{C\&M}$, especially economic growth (Lacey, 2008b). Especially economic growth, but not only it! For the interest of economic growth overlaps with other interests that are reflected, e.g., in technoscientific research producing advances in electronic technology that have considerable consumer appeal, advances in certain areas of medical treatment and in military technology, and the expectancy of more such advances in the short run. The value of technoscientific research can be linked to its alleged contributions simultaneously to $V_{C\&M}$, to individual well being and liberty, and to national security.²⁵ There are a variety of value outlooks, all well embodied in contemporary society, that can be portrayed as having dialectical links with V_{TP} and among themselves, and this provides strong stimulus to privileging DA, even to regarding it as integral to science, and to considering science as reducible to technoscience. Technoscience is research conducted within DA; and the objects it tends to investigate, the possibilities explored, (and some of the specific experimental methods used), are of special interest to those who hold $V_{C\&M}$; and a large part of funding for research is premised on the connection between scientific research, technological innovation, gaining competitive advantage, and economic growth.²⁶

Then, the value of gaining understanding of phenomena of the world is subordinated to expanding our knowledge of what we can do, of how we can expand our powers

²⁴ Schwarz (2012) suggests that Bacon's *New organon* already entertains this tendency, and so can be considered a forerunner of technoscience.

²⁵ The direction of research and development of technoscience, and what kinds of technoscientific objects there could be, is susceptible to change with the values with which it may become linked. Today, e.g., efforts are being made in many institutions to interpret $V_{C\&M}$ in balance with values of sustainability ("green technology"). Echeverría (2005) maintains there is on-going contestation for the values that influence technoscientific developments, and Feenberg (2009) refers to instances of where the values of users of technologies have strongly influenced the direction of their developments. It is important to recognize that current predominant tendencies of technoscientific development are not the only way to go; technoscience could develop in different directions, and technoscientific objects could embody different values. Bensaude-Vincent (2012) contrasts the US "technocratic vision" with the European "democratic vision"; the kind of public involvement in science that she discusses is premised on the recognition of the role of values in determining the direction of technoscience.

²⁶ Technoscientific research has other important characteristics that I will not discuss here. Shinn (2008) discerns in it the "transversal organization of knowledge", and the fundamental role of multidisciplinary groups and inter-institutional collaboration in the research process. Echeverría (2005) attributes the latter to the organization of technoscience being structured around grand projects that involve "converging technologies", e.g., nuclear weapons, missile defense systems, the human genome project, the US nanotechnology initiative, in such a way that the autonomy of the individual scientific disciplines becomes subordinated to the requirements of the grand projects.

to exercise control over objects, especially insofar as they can contribute to economic growth and other interests of leading commercial bodies.

This underlies an interconnected set of ethical stances being taken for granted. The implementation – and pursuit – of technoscientific innovations, *prima facie*, is considered to be legitimate, i.e., normally (subject to rebuttal) it is without any ethical impediments, as if an (unstated) ethical principle, somewhat like the following, overshadows scientific practices of research and application:

Ceteris paribus, unless standard risk assessments confirm that there are serious risks, it is legitimate to implement – without delay – efficacious applications of impartially confirmed technoscientific knowledge, and even to tolerate a measure of social and environmental disruption for its sake.

I call this the *Principle of the legitimacy of technoscientific innovations*. It goes hand in hand with it being considered virtually an ethical imperative to prioritize technoscientific “solutions” for the big problems of the world, e.g., malnutrition in poor countries, intractable diseases and new sources of energy, as well as for any harmful effects of technoscientific innovations (e.g., environmental damage) that may occur, and an ethical failing to cast doubt on the potential or the legitimacy of research and development that may lead to such “solutions” (Lacey, 2008a; 2008b; 2012).²⁷

This ethical viewpoint is readily intelligible if V_{TP} and $V_{C\&M}$ are held, and (a)-(d) (§4.4) and counterpart presuppositions of $V_{C\&M}$ (Lacey, 2005a, chapter 11) are endorsed; but not otherwise. It is rejected outright by those who hold the *Precautionary principle* (cf. Lacey, 2006). Technoscientific research produces results, that often are scientifically certain, that inform technoscientific innovations and explain their efficacy. The ethical viewpoint mediates making the move, *ceteris paribus*, from efficacy to legitimacy. But its intelligibility depends on holding particular (contested) value outlooks and endorsing propositions that cannot be properly investigated within DA, and of which it can be plausibly maintained that the preponderance of evidence is against them (see §4.5).

The legitimacy of technoscientific innovations can be appraised only in the course of considering fully what sorts of objects technoscientific objects are (see note 1). In the first place, technoscientific objects are objects that embody scientific knowledge confirmed within DA; they are physical/chemical/biological objects, realizations of

²⁷ This set of ethical stances is also linked with views about the inevitability of technoscientific advances and of the future being shaped by them; and hence of the importance of preparing people for this future that is in the making (cf. Roco & Bainbridge, 2002, discussed in Bensaude-Vincent, 2012).

possibilities discovered in DA research brought to realization by means of technical/experimental/instrumental interventions. Secondly they are components of social/ecological systems, objects that embody V_{TP} and (most of them) $V_{C\&M}$. A transgenic plant, e.g., is a biological entity, the outcome of technical intervention into a parent plant's genome, and so it embodies V_{TP} ; it is a component of an agroecosystem with worldwide dimensions; it is a commercial object whose uses are constrained by claims of intellectual property rights, reflecting that it embodies $V_{C\&M}$ – it has effects (and occasions risks) on human beings, social and ecological systems in virtue of all of the kinds of thing that it is.

What technoscientific objects are – their powers, tendencies, sources of their being, effects on human beings and social/economic systems, how they differ from non technoscientific objects – cannot be grasped from technoscientific inquiry alone. The knowledge that underlies and explains the efficacy of technoscientific objects is never sufficient for grasping what sorts of object they are and could become. ☞

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