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Editor, Davis Baird
Editorial Assistant, Aubrey Bryant

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Three Memetic Theories of Technology

Asunción Álvarez
asun_alv@yahoo.com
King's College, London

Introduction

Darwin's theory of evolution is undoubtedly one of the most elegant and powerful conceptual tools in contemporary science. Beyond its original scope within biology and genetics, it has been successfully combined with notions belonging to fields as apparently far-flung as economics (as in Game Theory or experimental economics). Following the interest shown by Darwin himself in the impact of evolutionary ideas on the explanation of human behaviour, attempts have also been made to dissolve the traditional nature/culture divide by extending the scope of Darwinian evolutionary thought to the human sciences – economics, psychology, anthropology, and sociology, among others.

In this paper I would like to introduce three theories of technology based on the evolutionary account of cultural transmission known as **memetics**, probably the least known of Darwinian theories of culture. Indeed, ever since its first formulations more than twenty years ago, the memetic research programme has reached a stage of stagnation, due in part to the lack of a single definition of its basic unit – the meme itself. This paper is thus mainly of an expository nature, given the multiplicity of theoretical trends that characterizes memetics, and the relative lack of literature comparing these approaches. These different trends are, I believe, best exposed and discussed by examining how they apply to the question of technology: for the nature of artifacts (and their conceptual counterpart, mentifacts) is, as we shall see, one of the main bones of contention in the wars of the meme.

The notion of memetic diffusion was launched by evolutionary biologist Richard Dawkins in his 1976 book *The Selfish Gene*, in which he hypothesized that living beings, including humans, are mere "vehicles" or "interactors" for the transmission of the genetic information they bear. Genes, said Dawkins, are "replicators," information units which generate copies of themselves in order to be transmitted from generation to generation; and evolution can be understood as directed by those replicators in order to preserve their continuity.

But in the last chapter of his book, "Memes: the New Replicators," Dawkins took a step further. Dissatisfied with the usual crude Darwinian explanations of human behaviour in genetic terms, he postulated the existence of a unit of cultural transmission, analogous to the gene, which he termed **meme**. Like genes, memes would be replicators, and the mechanism by which they produced copies of themselves would be *imitation*:

> Examples of memes are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or arches. Just as genes propagate themselves in the gene pool by leaping from body to body via sperms or eggs, so memes propagate themselves in the meme pool by leaping from brain to brain via a process which, in the broad sense, can be called imitation (Dawkins 1976).

The gene/meme analogy posited by Dawkins is meant to make possible an evolutionary treatment of human society and culture – a "Darwinization" of the study of man which would purportedly bridge the gap between the natural and the social sciences by way of the application of a biological (genetic) model to cultural transmission.

Memetics differs from other evolutionary accounts of human culture in the degree of independence it accords to the sociocultural domain. Unlike sociobiology and evolutionary psychology, whose ultimate aim is to reduce cultural behaviours to biological determinants, memetics accepts the existence of a dual mechanism of inheritance in the human species: biological *and* cultural inheritance. This is a thesis also upheld by the gene/culture coevolution approach in anthropology (also known as cultural selectionism). However, whereas coevolutionists argue that biology is ultimately preponderant, restraining the scope of sociocultural development (what is known as the “leash principle,” whereby genetic determinants would hold cultural development in check), for memeticists sociocultural behaviour is causally independent from biological factors, even though they may interact with each other.

Thus, the Darwinization of culture which constitutes the aim of memetics takes a different form from the reductionist claims of sociobiologists and evolutionary psychologists, as well as from the subservience of culture to nature posited by coevolutionists. According to memeticists, the memetic (sociocultural) domain must be explained independently from the genetic (biological) domain. However, this explanation must also be of an evolutionary character – yet not a reductionist or a biology-dependent one. In order to provide such an explanation, Dawkins has put forward the notion of *Universal Darwinism* – a generalization of Darwinian evolutionary principles that would span not only the genetic domain, but the sociocultural one too.

Universal Darwinism

The strategy of Universal Darwinism consists in abstracting the features peculiar to genes and organisms, which tend to be associated to the concrete material out of which they are built, taking into consideration only the roles played by **genotypes** and **phenotypes**. The genotype is the set of genes which an organism contains. The phenotype is any morphological, physiological or behavioural feature displayed by an organism that is caused by the interaction of its genotype with the environment. This abstract perspective makes it possible to see evolution as consisting in two fundamental processes:

(a) Replication: the process whereby genes become copied from generation to generation, ensuring that successive generations will be alike enough for cumulative selection to take place. The corresponding entity is the *replicator*, which Dawkins identifies with the gene.

(b) Ecological interaction: the relationship between organisms and their surroundings – including other organisms – which biases replication and ensures that the differences between successive generations are significant enough for mutation to take place. The corresponding entity is the *vehicle* or *interactor*, which Dawkins identifies with the organism housing the genes, and on which the phenotypic effects take place.

Thus, replication would be a function of an organism's genotypic makeup, whereas its ecological interaction would be linked to its phenotypic manifestations. This yields the following set of oppositions:

Genotype	Phenotype
Replication	Ecological interaction
Replicators	Vehicles / Interactors
Genes	Organisms

This highly abstract definition of evolutionary processes has made the extension of (Universal) Darwinian principles from biology to culture considerably easier.

Thus, memeticists currently strive to identify sociocultural equivalents for the concepts given above. The **memotype**, or genotypic meme, has been defined as the cultural analogue of the genotype, whereas the **phemotype**, or phenotypic meme, would be the cultural analogue of the genetic phenotype.

Insofar as it is a part of culture, technology can be approached from a memetic standpoint. Indeed, the nature of artefacts has been the main issue in the debate between three main currents within memetics, which differ in their respective definitions of phemotypes and memotypes. Standard, or cognitive/mentalist memetics, regards artefacts as phemotypes, i.e. as the phenotypic expressions of memetic genotypes, which would consist in mental representations. This is what I have termed the phemotypic theory of technology. The memotypic theory of technology posited by behaviouralist memetics, on the other hand, sees material culture itself as the genotypic blueprint out of which conceptual phemotypes are generated. Finally, Robert Aunger's theory of the neuromeme denies altogether the pertinence to the study of culture of the phenotype / genotype opposition.

The Phemotypic Approach

In his original formulation in *The Selfish Gene*, Dawkins cited “tunes, ideas, catch-phrases, clothes fashions,” and “ways of making pots or arches” as examples of memes. It is important to note that these are all instances of abstract concepts or ideas. Just as the way of making a pot is not the same thing as the pot itself, neither is a catch-phrase the unique, concrete utterance of an individual, but an abstract word sequence which can be repeated in multiple occasions by multiple individuals; nor are clothes fashions sets of concrete clothes, but sets of collective tendencies regarding clothes.

Daniel Dennett explicitly claims that memes *are* ideas,

> not Locke's and Hume's “simple ideas” (the idea of red, or the idea of round or hot or cold), but the sort of complex ideas that form themselves into distinct memorable units (Dennett 1996, 344).

Dennett identifies the genotype with the meme *qua* concept, the phenotype with the physical effects of such concept, and the vehicular organism with the phenotypic manifestations which transmit the memetic genotype. In this way, technology would be the phenotypic manifestation of a memetic or conceptual genotype:

> Genes are invisible; they are carried by vehicles (organisms) in which they tend to produce characteristic effects (phenotypic effects) by which their fates are, in the long term, determined. Memes are also invisible, and are carried by meme vehicles – pictures, books, sayings (in particular languages, spoken or written, on paper or magnetically encoded, etc.) Tools and buildings and other inventions are also memetic vehicles [...]. A wagon with spoked wheels carries not only grain or freight from place to place; it carries the brilliant idea of a wagon with spoked wheels from mind to mind. A meme's existence depends on a physical embodiment in some medium; if all such physical embodiments are destroyed, that meme is extinguished (Dennett 1996, 347-8).

He then goes on to give such examples of memes as the *ideas* of "the arch, the wheel, wearing clothes, vendetta, the right triangle, the alphabet, the calendar, the *Odyssey*, calculus, chess, perspective drawing, evolution by natural selection, Impressionism, *Greensleeves*, and deconstructionism."

Dennett explicitly opposes the thesis of neuromemetics (which we shall see in the next section) by which memes would have physical nature, and of a single kind at that. For Dennett, identifying the units of cultural transmission with brain patterns, as Robert Aunger does, is a mistake analogous to identifying genes with complex DNA structures. Dennett has famously defined evolution as an algorithmic process. In his view, this algorithmic character of evolution implies that it must be describable in purely informational, substrate-neutral terms. Interestingly, Dennett also specifies that the memetic genotype – the meme proper, the concept or idea – would have a *syntactic* character (that is, it would be a purely formal entity, subject to meaningles mechanical procesess), whereas all its phenotypic manifestations would be of a *semantic* nature (that is, they would be characterized by the fact that they are entitites endowed with meaning, subject to interpretation):

> what is preserved and transmitted in cultural evolution is information – in a media-neutral, language-neutral sense. Thus the meme is primarily a semantic classification, not a syntactic classification that might be directly observable in "brain language" or natural language (Dennett 1996, 353-4).

By "meme," Dennett seems to refer here to the (semantic) phenotypic manifestations of (syntactic) mental representations. Ultimately, says Dennett, the syntactic concepts might in theory be reducible to the brain structures which embody them – but defining those brain structures would not prove too useful. Unlike genes, which are endowed by the existence of a single genetic language with "a satisfactorily strong alignment of semantic and syntactic identity," memes can only be identified by their "meaning," their phenotypic effects:

> It is conceivable, but hardly likely and certainly not necessary, that we will someday discover a striking identity between brain structures storing the same information, allowing us to identify memes syntactically. Even if we encountered such an unlikely blessing, however, we should cling to the more abstract and fundamental concept of memes, since we already know that memetic transmission and storage can proceed indefinitely in non-cerebral forms – in artefacts of every kind – that do not depend on a shared language of description (Dennett 1996, 354).

That is, Dennett assumes that there is in the case of genes a close correspondence, almost to the point of identity, between their internal configuration – their "syntax" – and their external effects – their "meaning." The fact that both the "syntactic" elements of genetics and their "semantic" effects are observable, and their high degree of coherence make it possible to use a unified vocabulary for both aspects of genetic dynamics. However, this is not the case in memetics, where conceptual memes are not empirical entities, but can only – and questionably – be identified by their effects upon the empirical world.

The correspondence between genetic and memetic terms in standard memetics would therefore be as follows:

	GENETICS	**MEMETICS**
SYNTAX	Genotype	Memotype; genotypic meme; mentifact; (ultimately) brain structure
SEMANTICS	Phenotype	Phemotype; phenotypic meme; artefact
	Vehicle / Interactor	Memetic vehicle / interactor

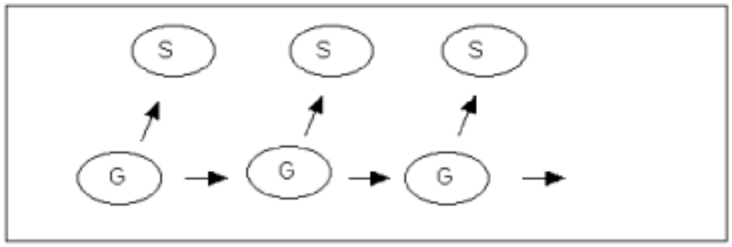
Thus, in this branch of memetics, which can be called "idealist" or "mentalist," technological artefacts are considered to be the semantic phenotypic expression of syntactic mental entities, or "mentifacts." Mentifacts, on the other hand, would constitute the genotypes giving rise to artefactual phenotypes in their vehicle-mediated interaction with the environment.

However, this standpoint has one serious drawback. There are two main differences between genetic and memetic transmission, which the evolutionary theorists John Maynard Smith and Eörs Szathmáry have put as follows:

> Genes are transmitted from parents to children: memes can be transmitted horizontally, or even from offspring to parent. But there is a deeper difference between genes and memes. Genes specify structures or behaviours – that is, phenotypes – during development; in inheritance, the phenotype dies and only the genotype is transmitted. The transmission of memes is quite different. A meme is in effect a phenotype: the analogue of the genotype is the neural structure in the brain that specifies that meme. When I tell you a limerick, it is the phenotype that is transmitted: I do not pass you a piece of my brain. It follows that in the inheritance of memes but not of genes, acquired characters can be inherited. If I tell you a limerick and you think of an improvement, you can incorporate it before you pass it on. In this sense, cultural inheritance is Lamarckian (Maynard Smith & Szathmáry 1999, 140).

According to the Lamarckian version of evolution, the characteristics acquired in the course of an organism's life can be passed on to that organism's offspring. Or, in other words, the variations in an organism's phenotype can be transmitted to its genotype and thus be inherited by the organism's offspring.

Genetic Lamarckism was refuted at the end of the 19th century by Augustus Weismann with his famous doctrine of the separation between germ and soma (better known as the *Weismannian Barrier*). According to this theory, the separation between those lineages of cells destined to become germinal or reproductive cells and the lineages of cells destined to become somatic or body cells would take place at a very early stage in embryogeny. The implications of this find were crucial, for it meant that whatever events may happen to an individual organism, they will not affect its progeny, as there is no way for them to be transmitted to its germinal cells. (In this way, for instance, if a man loses one leg, such loss is not reflected in his genotype, and his children need not be born lame). Thus, Lamarckian inheritance – the inheritance of acquired traits – was rejected.



The Weismannian Barrier

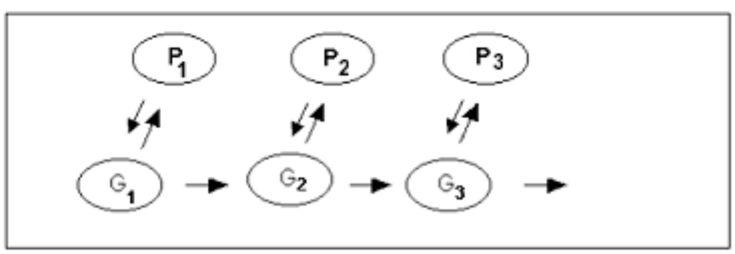
G = germ, or reproductive cells
S = soma, or body cells (organism)

Weismann's distinction between soma and germ corresponds to that between phenotype and genotype. In this way, the Weismannian Barrier can be reformulated, stating that the genotype produces the phenotype, but changes in the phenotype bear no effect upon the genotype.

Given the identification that idealist memetics establishes between the (replicating) genotype and the meme *qua* concept, on the one hand, and between the phenotype and the meme *qua* object, on the other, the characterization of processes of cultural transmission as "Lamarckian" would thus seem to have a certain plausibility. Dawkins himself contemplates such a possibility in his *Extended Phenotype*:

> The equivalent of Weismannianism is less rigid for memes than for genes; there may be "Lamarckian" causal arrows going from phenotype to replicator, as well as in the other sense (Dawkins 1992, 112).

That would result in a scheme similar to this:



Memetic Lamarckism

G_x = genotypic meme or memotype
P_x = phenotypic meme or phemotype

One of the most common objections to Lamarckism is that most of the changes effected on organisms by the environment are non-adaptive: they are usually the result of injury, disease, and aging. A genetic system which had a mechanism of "reverse translation," by which information about the adult phenotype might be incorporated to the genetic message passed on to the next generation, would lead to degeneracy, not to adaptation. But, as Maynard Smith points out, if there were some way of selecting for transmission only those phenotypic traits which would prove adaptive, not only would adaptive change endure, but it would also speed up. Indeed, that is precisely what cultural evolution is all about. As Szathmáry has expressed it,

> whereas genes are weismannian replicators, with no flow of information back from the phenotype, memes are lamarckian ones, relying on reverse encoding from the phenotype, as if genetics canonically included something akin to reverse translation, or at least to some other means of inheriting acquired traits. The immediate consequence is higher variability and the potential for cultural evolution to be much faster than genetic evolution (Szathmáry 2002, 370).

The Neuromemetic Approach

Recently, Robert Aunger has put forth in his book *The Electric Meme* an extreme version of mentalist memetics which he has termed neuromemetics. Neuromemetics differs from standard memetics in that it defines the meme as

> a configuration in a node in a neural net which is able to induce the replication of its state in other nodes (Aunger 2002, 197).

By "node," Aunger seems to mean a neuron or set of neurons that have a given state and cause another neuron or set of neurons to acquire that state. This definition avoids the identification of memes with neurons: the neuromeme would be a *brain state* rather than the *material substrate* supporting it. However, Aunger's view differs from standard memetics in its denial of the substrate-neutrality of memes. Whereas the standard view has it that meme lineages can jump across different material substrates, from brain to computer to book to another brain, Aunger holds that neural nets are the only possible material substrate in which memes can thrive. Thus, even though he avoids the equation of concepts with neurons, Aunger holds a resolutely physicalist view of memetics in that he identifies the units of sociocultural transmission with neural patterns – and *only* with neural patterns.

The most startling consequence of the neuromemetic approach is that, while identifying memotypes with neural states, it has no memetic equivalent for phenotypes. In interpreting the signals through which genotypic memes transmit themselves in the environment outside the brain as vehicles or interactors, standard memetics lays itself open to the charge of Lamarckism: and evolution, according to Aunger, cannot possibly be Lamarckian, ever. This forces Aunger to develop a baroque ontology in which signals would not be phemotypes, but meme-produced "instigators:"

> Calling signals instigators instead of interactors or vehicles is crucial because it saves us from the ghost of Jean-Baptiste Lamarck. If signals are not interactors, then cultural evolution does not imply the inheritance of the traits derived from an interactor – Lamarck's folly (Aunger 2002, 241-2).

But, obviously, merely *calling* signals one thing or another will not do. In what ways does an "instigator" differ from a plain vehicle, that it may escape the Lamarckian curse? Aunger describes instigators as "mass agitators" that would spare memes the task of establishing contact with each other. For Aunger, the processes of memetic replication are not really transmission but *conversion* processes in which the neural substrate takes a determinate configuration. Instigators would thus be some sort of replication catalysts, and would have the additional advantage of avoiding the risk of informational degradation inherent to conversion itself.

But if signals are not phenotypic in nature, what are they instead? Aunger will not say. As Eörs Szathmáry has pointed out in his review of *The Electric Meme*, Aunger "seems to miss the point that a set of signals associated with a meme is in fact its phenotype" (Szathmáry 2002, 370).

The Memotypic Approach

Given that the whole memetic enterprise is based upon the extension of the genetic model to the cultural domain, the cultural Lamarckism which the phemotypic trend seems to ultimately imply is an embarrassment for certain theorists – Lamarck being, as we have seen, somewhat of a *bête noire* in evolutionary thought.[i] There is, however, yet another current within memetics which is meant to avoid the alleged pitfalls of Lamarckism by providing an alternative to the identification of the genotype with the mental meme. This school of thought has been termed behavioural or externalist memetics, as opposed to standard mentalist memetics, and its main proponents are William Benzon and Derek Gatherer. In his essay *Culture as an Evolutionary Arena*, Benzon suggests

> that we consider the totality of physical culture as [cultural] genes [i.e. memes]: pots and knives, looms and tanned skins, utterances and written words, ploughs and transistors, songs and painted images, tents and stone fortifications, dances and sculpted figures, everything. For these are the things that people exchange, through which they interact. They can be counted and classified and studied in various ways (Benzon 1996).

According to this view, memes would constitute a heterogeneous class of entities, comprising both behaviours and artefacts – the observable things that make empirical research possible. In fact, Benzon turns the correspondence established by standard memetics on its head, identifying phenotypes with the mentifacts generated by the genotypic memes embodied in material culture:

> What I propose in fact is that we think of these mental objects and processes as analogous to the phenotype in the same way as physical objects and processes are analogous to the genotype [...]. Whereas biologists speak of a gene pool, genes never actually mingle in a physical pool. Genes are DNA chains inside cells. The gene pool of a species exists as a logical fact, not as a physical pool full of genetic slime. It is the phenotypes of species that mingle in the physical pool of the environment. In culture, it is phenotypic traits that are inner whereas genetic memes are out there in the physical pool of the environment. When cultures meet, their memes mingle freely (Benzon 1996).

Genotypic memes, the true memetic units, are thus identified with artifacts because artifacts are more readily available for quantification and empirical study given their physical, discrete existence. Derek Gatherer takes up Benzon's thesis, giving as further support the neurological conjecture that it is highly improbable that there be information-replicating structures in brains.

Gatherer (1998) distinguishes two different definitions of the meme – both given by Richard Dawkins – which he terms the Dawkins A version and the Dawkins B version.

> **Dawkins A**: "... a unit of cultural transmission, or a unit of imitation" (Dawkins 1976, 206). "Examples of memes are tunes, ideas, catch-phrases, clothes fashions, ways of making pots or of building arches" (Dawkins 1976), "… memes for blind faith have their own ruthless ways of propagating themselves" (Dawkins 1976, 213).
>
> **Dawkins B**: (referring to the original Dawkins A definition, above) "... I was insufficiently clear about the distinction between the meme itself, as replicator, on the one hand, and its 'phenotypic effects' or 'meme products' on the other. A meme should be regarded as a unit of information residing in a brain... It has a definite structure, realized in whatever physical medium the brain uses for storing information... I would want to regard it as physically residing in the brain" (Dawkins 1982, 109). "The phenotypic effects of a meme may be in the form of words, music, visual images, styles of clothes, facial or hand gestures..." (Dawkins 1982, 109).

According to Gatherer, Dawkins's latest reformulation – Dawkins B – lost the elements which constituted the strength of Dawkins A. Dawkins A referred to observable cultural entities – changes in cultural states within groups, with no mention to what might be happening inside the heads of the members of those groups. By contrast, Dawkins B focussed on non-observable, merely inferred events. "Since memetics is a theory of cultural evolution," states Gatherer, "Dawkins A is preferable as *it allows us to look at culture*." Given that memetics is meant to be a science of culture, not of psychology, it ought to describe change in populations by quantifying such cultural phenomena as artefactual forms.

Gatherer attributes the stagnation in which memetics has remained for more than two decades to the emphasis placed on the Dawkins B formulation – which is the basis of mentalist memetics. According to Gatherer, a return to the first definition of the meme would prove highly advantageous: besides allowing the identification of observable and definable units, behaviourism would also free memetics from the cumbersome need of defining a meme / host relationship, as artefacts seem not be host-based, but to propagate independently from their creators.

Conclusions

Thus, the perspectives on the genotype / phenotype opposition in memetics can be summed up as follows:

	Cognitivist / mentalist / representational/ internalist memetics	**Behavioural / externalist memetics**	**Neuromemetics**
Memotype (memetic genotype)	Mentifacts	Artefacts	Brain configurations
Phemotype (memetic phenotype)	Artefacts	Mentifacts	?

The contrast between the phemotypic, the neuromemetic, and the memotypic theories of technology can be seen as a new form of the mentalist/behavioural opposition lying at the heart of the debate which raged between traditional behaviourist psychology and the new cognitive sciences in the 60s and 70s. The standard view of memetics that regards artefacts as phemotypes or phenotypic expressions of concepts which would be their memotypes or genotypic blueprints is a version of the mentalism which characterizes cognitivism. In fact, the rise of cognitivism as the current prevailing paradigm in psychology and philosophy of mind has brought about a certain consensus in academic circles to consider culture as consisting only in mental entities. The standard version of memetics, with its phemotypic theory of technology, is arguably a result of this consensus. Indeed, it has been precisely one of the foremost cognitivist philosophers, Daniel Dennett, who has given the paradigmatic example of standard memetics's theory of technology. In regarding a spoke-wheeled wagon as a memetic vehicle (i.e. a phenotypic meme, or phemotype) which serves to spread the genotypic meme or memotype (the *idea* of a spoke-wheeled wagon), Dennett remains within the mentalist, representational tradition of cognitivism. Thus, in this internalist version of memetics, technology is seen as the phenotypic manifestation (phemotype) of a conceptual genotype (memotype) lodged in human minds (hence our terming this approach to technology *phemotypic*).

In its most radical, *neuromemetic* form, to the mentalism of standard memetics is added an orthodox Darwinian rejection of Lamarckism, yielding a rather muddled theory which is to all effects unable to account for cultural transmission *outside* the brain. According to the neuromemetic point of view, Dennett's spoke-wheeled wagon is somehow an "instigator" caused by neuromemes that in turn elicits memetic replication in the brains that come into contact with it – presumably, moving people to try to reproduce the wagon. Exactly how this is done remains a mystery, given that Aunger refuses to acknowledge the fact that anything produced by the genotype in response to the environment *is* its phenotype. Neuromemetics is thus able to offer an explanation of memetic dynamics as long as they remain memotypes lodged within the brain, but signally fails to provide an account of their phenotypic transmission in the outer world.

By contrast, behavioural or externalist memetics restricts its theorizing to observable entities and events, refusing to take mental representations into account given their non-verifiable character. Or rather, behavioural memetics *does* take mental representations into account, but not as the starting point for its analysis of cultural transmission. Externalist memeticists stress the need for discrete, definable units if a proper analysis is to be undertaken: and obviously mental representations do not meet these requirements – empirical research can only deal with physical things. While externalist memetics admits the existence of mental representations, it relegates them however to a secondary status, regarding them as the phenotypic by-product of material culture – the memotype.

It can be argued against the memotypic theory of technology that methodological needs in research do not necessarily reflect the nature of the things researched. True, we can observe only material culture, whereas mental representations are largely a matter of subjective introspection, and thus not much use for empirical research. But this does not automatically lead to the conclusion that material culture generates mental representations. Methodological precedence does not entail causal precedence. Therefore, whereas the claim of externalist memetics that only artefacts constitute appropriate units for the study of sociocultural transmission is quite reasonable, its identification of material culture with the genotype and of mental representations with the phenotype is more questionable.

The fundamental motivation for all evolutionary accounts of human behaviour is the denial of any discontinuity between mankind and the rest of species, between culture and nature. Even taking this (I believe) doubtful premise for granted, the application of *biological* models to cultural phenomena, given the range and complexity of the latter, remains problematic. Furthermore, there is no single evolutionary account of cultural phenomena, but a wide array to choose from. And even if we were we to accept the plausibility of a memetic account of culture and technology, and prefer memetics to other evolutionary alternatives, there would be yet a further choice to make – *which* memetics?

As I hope to have shown, the question of which memetic theory is most acceptable would seem to pivot on the dilemma between admitting some sort of sociocultural Lamarckism (the phemotypic option) – which seems unacceptable from a standard evolutionary point of view – and embracing a purely materialist account of sociocultural transmission (the memotypic option). Are we to allow for the possibility that the astonishing rate of technological progress in the human species is due to some sort of phenotypic feedback? Or is cultural evolution best modelled by regarding material culture as the genotypic blueprint for the mental representations it gives rise to?

My own leanings tend towards the first option, the phemotypic version of memetics, according to which mental representations play the role of genotypic blueprints for phenotypic artifacts. As I mentioned before, behavioural memetics – as, indeed, behaviourism as a whole – seems to me to be founded to a large extent on methodological ease and, while not denying the reality of mental representations, does nothing to explain them. Benzon and Gatherer have stressed the desirability of a quantitative approach to the study of society and culture, but the human sciences have already been provided with mathematical tools, such as statistical analysis, that sufficiently cover this ground. The methodological shortcut of overlooking (while not denying) mental representations in order to focus on the behaviour of the observable entities, i.e. of artefacts, thus seems unwarranted, as techniques to deal with diffusion rates and transmission patterns are readily available. What makes memetics interesting, I believe, is precisely its attempt to provide (in its mentalist version) an evolutionary account of the transmission of information from mind to world and back to mind.

Behavioural memetics also seems to be based on a fear of Lamarckism, which, while understandable in genetic research, is more questionable in the cultural domain. Indeed, the transmission of acquired traits is precisely what culture is all about. It can be argued nevertheless that applying a model which originally belongs in a given field to a different one – i.e. the application of the (biological) evolutionary model to the cultural domain – only to eschew the features of that model which prove awkward for the new field – i.e. the Weismannian barrier – is an unacceptably amateurish and *ad hoc* solution. Certainly, if we consider that biological and cultural phenomena, being essentially the same sort of thing, must be accounted for in the same terms, the Lamarckism of phemotypic memetics renders it useless. However, if we consider that the complexity of the cultural domain calls for an independent account – as, like we said, was originally the case with memetics, unlike cultural selectionism, evolutionary psychology, and sociobiology – then it might be permissible to adopt the genetic evolutionary mode in order to modify it as needed, retaining its main traits and adding whatever peculiarities the cultural field might require. In this view, the Lamarckism of phemotypic memetics would not be a weakness of the model, but rather its main strength.

As we have seen, the question of the nature of artefacts is the main battleground for the various versions of memetics. However, memetics has so far displayed a remarkable lack of empirical research. In this sense, a detailed study of concrete technological developments would be tremendously useful to assess the validity of either version of memetics. It is this empirical direction that memetics must take in the future in order to sustain its general claims concerning the nature of cultural transmission, as well as to attain a unified theory.

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[i] However, the disrepute of Lamarckian notions has been recently questioned even in the genetics itself. Cf. Steele, Lindley & Blanden (1998).

A Model-based Approach to Technological Theories

Ana Cuevas-Badallo
acuevas@usal.es
Lecturer at the Philosophy Department.
University of Salamanca (Spain)

Abstract

Several authors have studied and pointed out the main characteristics of engineering sciences. This paper deals with the analysis of one of these sciences, strength of materials, and shows how the practical goal of this science may have epistemological consequences. For this purpose, the model-based explanation of scientific theories proposed by Ronald Giere, especially his "similarity" relationship, is also discussed. Regarding engineering sciences, it is remarkable how important practical purposes are when developing and consolidating theories. The last section is related with the possible different reasons for building a set of models from the engineering point of view. [1]

1. Introduction

Philosophers of technology — those who deal with the consequences of technological developments as well as those who have proposed an analytical characterization — agree on pointing out that there is a close relationship between technology and science. In quite recent works,[2] some of them show us that while it is true that technology depends on science to develop the basic knowledge required for innovation, it is also true that contemporary science would be impossible without technological artifacts used in observation, experimentation, and the designing of models. Therefore, the definition of technology as an applied science widespread among certain groups of philosophers of science in the second third of the last century is now considered a useless simplification created in order to understand the complex nature of technology.

Some historians, like Edwin Layton; economists, like Nathan Rosenberg (Rosenberg 1982), Richard P. Nelson (Nelson 1982) and Christopher Freeman (Freeman 1982); engineers, like Walter Vincenti; and philosophers, like Joseph Agassi, Friedrich Rapp, and Ilkaa Niiniluoto, went even further and pointed out that sometimes technological developments may require new technological-scientific knowledge: the so-called engineering or technological theories.

The first research about technological knowledge dealt almost exclusively with operational knowledge or know-how. This operational knowledge was often subjective in nature, different from all good theoretical knowledge (Drucker 1961, 1963; Hall 1962; Feibleman 1966). Some philosophers appropriately claimed that know-how is not the only kind of proper technological knowledge: they had forgotten the kind of knowledge required in designing complex artifacts. Know-how alone — at least the kind of know-how that a craftsman should have — is not sufficient. This seemed a good reason to start defining know-how of a high level, and highly sophisticated operational knowledge, no longer beyond words but still without the degree of elaboration of any scientific theory (Bucciarelli 1988, 1994; Vincenti 1990, 207-225; Petroski 1992, 1996; Constant 1999). At the present time there is another line of research dealing with the knowledge that emerged during the manufacturing process of artifacts (Baird 2000, 2001a, 2001b, 2002). All these studies have been very interesting and relevant in gaining a better understanding of technological knowledge. However, is there not any other task for the epistemology of technology? I assume there are two different answers to this question, each of them leading to equally different attitudes. Those who maintain that the only theoretical knowledge involved in technology comes from developments in natural, formal or social sciences would have to agree that the kinds of studies mentioned above are all that we can expect regarding the "epistemology" of technology. On the other hand, as some authors think plausible, if one admits certain technological-scientific theories as one of the elements of modern technology, then there is a field for epistemological inquiry concerning particular features of this kind of knowledge; methodology involved in these researches; characteristics of the outcomes; roles of theories, laws, and hypotheses in the process of developing knowledge, and in the process of designing and manufacturing technological artifacts; and, finally, the relationships between these technological theories and the scientific ones.

This paper attempts to show an epistemological revision of one of these theories, strength of materials, and describe it as a scientific theory in a similar sense as Ronald Giere has proposed.[3] Strength of materials fits quite well with Giere's description of scientific theories, but it has stronger practical applications and a clear epistemological significance.

2. Precedents

More than a few authors, among whom are Mario Bunge (1966, 1967), Edwin Layton (1971, 1974, 1976, 1979, 1987), Ladislav Tondl (1973), Joseph Agassi (1980, 1985), Fredrich Rapp (1981), Walter Vincenti (1990, 2001), and Ilkaa Niiniluoto (1995),[4] suggested that technologists themselves are able to develop theoretical knowledge. All of these authors distinguished a group of sciences not included in the more habitual classifications, and agreed these special sciences share many features. As sciences, they require experimental research and mathematical language (Rapp); they deal with the same laws of nature as the rest of sciences (Bunge, Rapp, and Vincenti); they are both descriptive (Rapp and Niiniluoto) and predictive (Rapp and Bunge); their outcomes are shared and taught in similar ways of communication and training as the other sciences have been (Layton and Vincenti); they are a result of the division of labor (Tondl, Layton, and Vincenti); and the development of their knowledge is cumulative (Layton and Vincenti[5]). In spite of many discrepancies among these authors, all of them agreed on this: the practical goal that directs these sciences is what makes them different from the other sciences. Engineering scientists work with the aim of designing and producing artifacts, while other scientists build up their theories so as to get a better comprehension of observable phenomena.

These contributions made it possible to question the simplistic idea that all theoretical knowledge comes from natural sciences and then is applied to technology. Obviously this idea is still widely accepted. For instance, in the cases of Bunge and Rapp, there still remains the tendency to consider this knowledge the result of certain processes of transformation (never adequately explained) of previous knowledge developed by natural scientists. This tendency is derived from the privileged relationship some philosophers consider to exist between scientific knowledge and reality: scientific theories provide accurate knowledge about the world (realism), and the artifacts created based on that knowledge supposedly validates this thesis.[6]

This idea is just partially correct. First, it is not plausible that *all* natural scientific theories may be applied in order to design a technological device (this is a widespread opinion and does not deserve more attention). Secondly, in order to explain the highly sophisticated knowledge involved in designing and manufacturing technological artifacts, certain scientific theories are necessary. However, in many cases, current scientific theories cannot adequately solve every problem emerging during technological processes, and technologists themselves must face up to the task of developing their own theoretical knowledge. Artifacts manufactured through such a process work effectively, though with limitations. The fact that these artifacts validate use of technological knowledge implies a non-naïve realism.

Recent developments in theory of science show different possibilities with the aim of defending this non-naïve realism that does not have the same defects of the former realisms. It is the case with Ronald Giere and his realist constructive perspective:[7] his perspective is realist, because from the ontological point of view, he considers that the world exists independently of our knowledge. Likewise, from the epistemological point of view, he does not accept skepticism and assumes that it is possible to know entities in the world, though in a different way than that in which a realism without restrictions would maintain (Giere 1988, 95). Giere's view is commonly framed in the so-called "semantic view of theories," in which other well known philosophers such as Patrick Suppes, Frederick Suppe,[8] and Bas van Fraassen have made important contributions. The semantic view was conceived as an alternative to the "syntactic approach" of the received view. Instead of sets of true propositions about the world, theories are now better understood as sets or clusters of models. It is generally considered that the relationship between models and the world must be an *isomorphic* one. Nevertheless, Giere considers it more accurate to say that the relations between models and the world are *similarity relationships*. There are no true theories, only catalogues of cases in which models "fit" well enough with systems of the world.[9] These models are generated by scientists using general principles and specific conditions (Giere 2003, 5). General principles —which in other perspectives are scientific laws — are not universal truths, but, at best, truths consensually agreed upon by scientists for a specific model or cluster of models.[10] The degree of similarity will depend on pragmatic issues and not just on ontological and epistemological ones. The basis for choosing between different similar models is one of the more controversial aspects of Giere's perspective. A new possibility for engineering sciences will be introduced in sections 4.3 and 4.4, where different values and their importance in strength of materials are suggested.

Another interesting feature of Giere's realism is the incorporation of some constructivist elements generally considered contrary to traditional realism. He maintains that science is made by human beings. This is certainly an obvious characteristic, but it is also frequently forgotten. Scientists, as intentional agents, use models in order to represent some aspects of the world with determined purposes. From the very beginning, some values are involved in the choice of the

best model, the most important being to prefer a model that provides the most accurate potential representation. The scientific community will help to reach a consensus regarding validity of motives.[11]
Nevertheless Giere's approach does not imply any relativism from the ontological point of view. Scientists choose those aspects of phenomena they are going to deal with, that is to say, the properties they consider relevant to their purposes, while ignoring others.[12] This is not to say that scientists "invent" reality, the position which a more radical constructivist would defend, but rather that the world is complex enough so as to admit different models about the same phenomena without necessarily implying that only one of them is correct.[13] It all depends on the purposes for which the models are devised.

However, in the case of the engineering sciences, Giere's constructive realism may be interpreted as having instrumentalist characteristics. This claim could be controversial, because some philosophers tend to think of instrumentalism as a kind of relativism not compatible with realism. However, this is not the case, al least, for engineering sciences. When something works in the world effectively it is not a relative matter, nor is it simply to prefer the most adequate model for achieving that goal. On the other hand, to maintain an instrumentalist position regarding the engineering sciences does not necessarily mean that this philosophical interpretation of the nature of scientific theories is appropriate for other kind of sciences. The reason why the scientific community prefers — temporarily — one model instead of others is not necessarily to choose the model that allows them to build the most efficient artifact. Nevertheless, this could be the most important reason for scientific-technologist communities to consider this model.

The time has come to introduce strength of materials as a theory with both practical and epistemological value. If it is possible to show that this engineering theory can be considered as a cluster of models based on general principles and specific conditions, that these models represent some aspects of the world, and that they have been generated and are effective in accomplishing specific purposes, then there is no good reason to separate this science from other scientific disciplines.[14] Of course, strength of materials has special features derived from its different pragmatic status: practical goals have epistemological effects on theories. Nevertheless, the fundamental structure of this technological science is no different from the structure of other scientific theories. Let's now take a look at the shape of the models, the principles on which these models are based, the specific conditions that the models refer to, and the purposes that direct strength of materials.

3. Strength of Materials in textbooks.

Textbooks are the standard form for displaying scientific theories, as well as the key tool for transmitting knowledge in our society (Giere 1988, 63; and Giere 1999a, 50). Theories appear in these books in their most developed and corroborated version. Although textbooks — as Kuhn accurately pointed out (Kuhn 1970, 137-138) — may be neither the source for the historical reconstruction of the sciences, nor the most up-to-date versions, those books can accurately describe theories from the scientists' point of view. This section analyzes some noteworthy handbooks on strength of materials from different times: the works of Stephen Timoshenko (1930, 1935, 1953), considered the founder of modern strength of materials; P. A. Stepin (1963); A. A. Ilyushin and V. S. Lensky (1967); Ivan Feodosiev (1968); Bela I. Sandor (1978); G. S. Pisarenko, A. P. Yakovlel, and V. V. Matveev (1979); and, Nicholas Willems, John T. Easley, and Stanley T. Rolfe (1981).[15]

Giere (1988) presents the example of the pendulum in theoretical mechanics and analyzes all the models and simplifications used in the textbooks related to it. In this paper, instead of doing something similar, choosing a single structural element among the formulas of the strength of materials, the whole theory will be considered. The reason for doing that is because strength of materials is not as well known as the mechanics. I realize the difficulty of showing all the features of a complex theory within the length of this paper. Nevertheless, the purpose of this article is to open the possibility of understanding engineering sciences from a modelistic point of view. Future work will be done in order to analyze the particular structural elements.

3.1. Definition, justification, and subject matter.

All these textbooks start with a definition of the discipline, offered immediately after a justification of the field because of its usefulness for designing effective artifacts. Usually, the books propose that strength of materials studies the relationships between external loads applied to a body and the effects of the loads on the internal structure of that body. It is worth noting that all these texts propose that, with the knowledge provided by strength of materials, it is feasible to calculate the *necessary and safe* dimensions of different parts of structures or pieces of machines.

Following the definition and justification, the three main issues the theory deals with are distinguished: first, a study about internal stresses presented in materials; secondly, studies in order to determine different plastic and elastic deformations that bodies- such as elements of structures and components of machines- can undergo under the action of external forces or loads (in terms of the theory); thirdly, the theory deals with the main concepts of strength of materials: stability, fatigue, and failure of components in some structures. The aim of strength of materials is to build the knowledge necessary for constructing artifacts that can effectively sustain the conditions they are going to be subjected to during their life.

3.2. Idealizations and simplifications.

Once the definition and the usefulness of the theory have been settled, and different properties of the bodies have been explained, the textbooks propose an explanation of the idealizations and simplifications that the theory assumes. The authors explicitly show the specific characteristics of materials that are relevant for the theory, while ignoring those properties irrelevant to the engineers' purposes. The authors know (and they explicitly say so) that on many occasions the characteristics they consider relevant may contradict conclusions reached by other scientific theories,[16] though the engineers accept these special features for the sake of applicability.

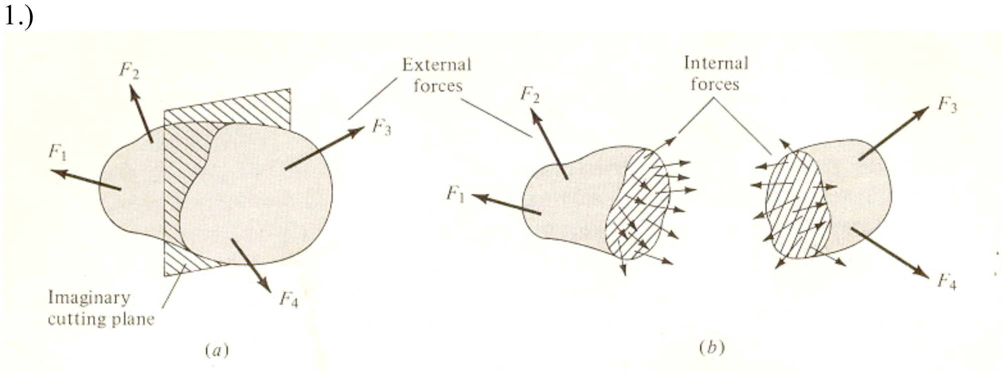
(I) First, the *properties of materials* are idealized. Thus, materials are considered as *homogeneous and continuous,* despite the internal properties of different materials.[17] The concept of continuity is derived from the concept of homogeneity, due to the fact that matter totally occupies a solid's volume. The assumption of the homogeneity property allows the applications of infinitesimal calculus to solids. Moreover, materials are usually considered *isotropic,* that is, the properties in any part of the material are independent of the original angular orientation.[18]

(II) Secondly, the *shapes of materials* are simplified. The geometrical shapes of solids are reduced in strength of materials to four elemental forms: beams, plates, vaults, and solids.[19] Generally the textbooks provide illustrations of these forms together with some applications as parts of structures or of machines.

(III) Thirdly, the *systems of force* applied on different elements of structures are idealized. The study on these forces and the deformations generated by them are, properly speaking, the theory's core. From a more general point of view, the textbooks distinguish between *external* and *internal* forces. The first third of the textbooks is usually dedicated to the study of internal strains and the second part to the analysis of external forces or loads.

3.3. Strains and deformations.

Internal strains are determined by the interaction between parts of the body, within well established limits. It should be noted that internal forces work between particles contiguous within the body affected by the load. Indeed, that property is essential to define the solid's limits, since forces that are external to a system may be internal in another, and vice versa. With the aim of determining these internal forces, the authors apply the *method of cross-sections*. The method consists of getting a beam mentally cross-sectioned into two parts. "Internal forces determine the interaction between the particles of a body on the different sides of the section passed through the body" (Feodosiev 1968, 20). According to the action and reaction principle, internal forces are always reciprocal.[20] (Figure 1.)



The concept of *stress* is used to characterize the law of distribution of internal forces in a cross-section, since stress will be the measure of intensity of internal forces. The total amount of stress in a point of the cross-section is a vectorial magnitude, being analyzed in three components: one *normal stress* and two *tangential stresses*. An accurate calculus of stress is essential to decide whether or not a given structure fulfills the safety conditions. Therefore, engineers need to know the purpose of the structure before doing any calculation.[21]

Following the discussion, authors then show how the ideas of *strain* and *deformation* can be used to construct effective artifacts. The authors usually present these examples side by side with graphic representations, as well as the corresponding mathematical calculi.

The textbooks discuss the relationship between strain and deformation, and clarify the fundamental difference between strength of materials and other theories, such as Newtonian mechanics (statics and dynamics). Physicists postulate that all bodies are perfectly rigid; they assume that the shape of bodies does not change under external loads. Nevertheless, as a matter of fact, all the shapes of material bodies change when they are subjected to external loads, though to a different degree. Despite the fact that those changes can be small, they are very significant, and must be acknowledged in order to build safe constructions. These changes are referred to as *deformations*, and involve the action of strains. Engineers define normal strain as changes in the length of bodies under the effect of a load. The calculations are proposed to avoid the physical breakdown of the material under strain. The textbooks include diagrams that show the different relationships between strain and deformation of different materials.

Since stress is proportional to load and strain is proportional to deformation, it implies that stress is proportional to strain. The next formula expresses the ratio between strain and stress:

$$\sigma = E\,\varepsilon$$

E means the proportionality coefficient (a physical constant of the material, experimentally obtained and measured in kg/cm^2). It is also called the elasticity module or Young's module. s is the normal stress, and ẹ is the normal strain. This formula is also known as Hooke's law,[22] and engineers consider it to be an approximate law, since "for certain materials, such as steel, it [Hooke's law] holds with a high degree of accuracy over a wide range of stress. In some cases, however, noticeable deviations from Hooke's law are observed" (Feodosiev 1968, 37). In those cases where the principle is not applicable, engineers calculate deformations with a function (obtained from experimentation on the material) that describes the curve of the specific material.

The different textbooks reveal that the behavioral relationship between strain and deformation of a great number of materials varies because of different rates of load and temperature. Therefore, engineers do different experiments in order to know the exact rates for each material.

Hooke's principle is generalized and shown as a set of basic equations. These equations are applicable to different structures with the aim of calculating stresses in a linear-elastic area. The books also describe many instances in which Hooke's law is applied to different materials and structures, and show how the law varies depending on conditions, materials, and structures.

So far the considerations have been about strain and deformation. The next sections discuss the analysis of different kinds of external loads.

3.4. Analysis of loads.

External forces or loads are divided into six different kinds: (i) body forces, (ii) surface forces, (iii) concentrated loads, (iv) distributed loads, (v) static loads, and (vi) dynamic loads. All these different loads are distinguished with the aim of simplifying the complex external loads acting on a structure. Body forces (for example, weight and magnetic forces), are considered to be distributed in the solid's volume, and applied to every particle of the body. Surface forces refer to specific areas of the surface, and are established at the point of contact between objects. Concentrated loads are concentrated in specific parts of the bodies. Distributed loads are distributed along the length, the surface, or the volume. Both concentrated and distributed loads may be considered *static* or *dynamic*. Static loads are applied to structures in an extremely gradual manner, "increasing from zero to their final value, and then either do not change their magnitude, direction or point of application with time at all or change them very slightly, so that accelerations occurring in this case can be neglected" (Stepin 1963, 17). Loads are dynamic when they "vary in time with great speed (for example, impact loads of short duration)" (Stepin 1963, 17). The authors take into account the case of *periodically repeated loads:* those cases in which the change of loads is periodically repeated and in which maximum levels of loads are continuously repeated after a period of time.

Once the general characterization about loads is proposed, the textbooks distinguish between different kinds of loads: torsion, tension, and deflection. Hooke's law, as well as Saint-Venant's principle, is used in the explanation of these loads. According to Saint-Venant's principle, "At points of a body which are sufficiently distant from the places of application of loads, internal forces depend to a very small extent, on the particular manner in which these loads are applied" (Stepin 1963, 15). These principles are applied for the sake of simplifying the schemes of calculus. In other words, engineers realize that material properties are fundamentally more complex, but calculi obtained using these assumptions provide a range of outcomes more useful for their purposes. These three kinds of loads are discussed at great length in strength of materials textbooks.

Torsion is analyzed thus: "a bar (shaft) undergoes torsion, if at its cross sections twisting moment occurs, i.e. moments lying in the plane of the section. The internal twisting moments are generally produced by external moments."[23] At this point, the authors usually assume some properties about materials to support theoretical simplification. The simplest case of torsion, the torsion of a beam, is submitted, along with the formulas needed to calculate the deformation made by loads. Some examples are included in which different materials are subjected to dynamic and static torsions, and average values of the action of the loads are shown. Pictures of concrete models accompany the examples.

Tension is also considered. Again, using the example of a beam, tension is defined as occurring when "some forces are applied all along the beam's axis but in opposite directions. In that case there is a displacement of advance in the cross-sections all along the beam's axis."[24] The authors propose formulas for possible idealized forms with both static and dynamic loads. Once more, numerous illustrative examples are offered. The authors incorporate beams and bolts in their experiments to show how different materials behave regarding their shapes and sizes. These sizes are offered between minimum and maximum rates.

Deflection "entails the deviation of a straight beam's axis or the change of curvature of a curved beam."[25] The textbooks present some methods to determine deflection of beams, along with several examples of elastic and plastic materials, as well as beams composed of two materials. In many textbooks, authors offer tables where kinds of loads, maximum moment, deviation equation (that is, the deformation), and maximum deviation appear related.

Once different loads have been explained, the authors consider cases in which these different loads are combined. The principle of superposition (principle of independence of action and addition of forces) is assumed to be applicable for the

solution of most strength of materials problems. The textbooks show some methods for calculation, the most common being the circle of Mohr: a method that allows engineers to calculate the strain in different points of a material subjected to combined loads. The textbooks are again riddled with numerous practical examples applying this method.
All those models where different kinds of loads are analyzed and divided will be used by designers in order to build efficient and safe artifacts, being able to derive values for the different internal loads and stresses in a varied range of materials.

3.5. Failures, fatigue, and application in building.

The last third of the textbooks deals with practical applications of strength of materials to specific designs. The concepts of fatigue and fracture are also explained. Certain structures are technically acceptable if they fulfill all safety requirements. Given these considerations, strength of materials textbooks provide formulas to determine security factors of structures.

One of the main reasons materials fail is instability under a load. This lack of stability may be due to several causes: the support upon which the material rests might be insufficient, or calculation may underestimate the materials' thickness. The problem of failure is one of the main concerns of every engineer.[26] That is the reason that they study the critical load (the minimum load at which instability occurs) and the critical strain (the strain which goes with instability) concerning different forms (such as columns, beams, and sheets), and diverse materials (steel, reinforced steel, and cement, for instance).

Failures and discontinuities within materials themselves may contribute to instability. In ideal cases, materials are continuous, but in actual structures and machines, engineers need to make orifices, cuts, and gratings in order to have different parts joined. Engineers need to know how these modifications, as well as the actual conditions (such as temperature, or load magnitude), could affect the calculus of distributed strain on materials. The textbooks offer some possible cases applied to different materials, along with tables and the most common methods for calculating the ratio between discontinuities, forms, and typical loads materials are going to deal with (again with many examples).

Fatigue is the last analyzed problem. Fatigue usually appears when materials are subjected to repeated loads in many cycles. This is the main criterion engineers ought to take into account in order to warrant safety and reliability of machines or structures. The authors of strength of materials textbooks usually distinguish between short cycle fatigue, in which the number of loads is relatively small (fewer than 10^4); and long cycle fatigue, in which the number of loads is larger than 10^4. The behavior of the different structures under fatigue must be "modeled"[27] as accurately as possible through experiments in the laboratory. The most general types of experiments to test and measure materials' resistance to fatigue are: (i) laboratory short scale tests, in which engineers get information about the behavior of idealized forms of materials, and (ii) direct tests on actual components of machines or structures. The books offer instances of both types of experiments and different outcomes carried out with different materials.

Besides the systematic presentation of strength of materials, most of the textbooks include tables[28] that deal with: (i) standard physical properties (such as elasticity module, final resistance, and lineal expansion coefficient on the basis of the temperature) of regular materials (such as different types of steel, iron, brass, copper, aluminum, wood, titanium, and cement); (ii) properties of the wide flange sections properties, standard I-beam sections, equal and unequal angle sections; (iii) elastic curves for different kinds of beams; (iv) and torsion constants of several structures.

4. Epistemological summing-up.

So far the main issues strength of materials deals with have been shown.[29] It is time to interpret these characteristics in epistemological terms. The next paragraphs analyze this theory as a set or cluster of models with representational goals.

4.1. Definition of the subject matter.

The first thing the authors establish in the textbooks is to define those aspects of the world that strength of materials deals with. They state that strength of materials is used primarily for technological purposes. The texts focus on the relationships between loads or external forces and deformations of materials. It is necessary to idealize[30] some properties of real systems: materials are considered to be homogeneous, continuous, and isotropic, despite the fact that these properties are not accepted in other well consolidated scientific models. For the purpose of strength of materials, "these particularities are not very important, since strength of materials deals with the study of structures of which dimensions are much superior, not only to those of atoms, but to those of crystals also" (Feodosiev, 1968, 14).

According to the traditional view of scientific theories, it is possible to maintain that these assumptions are false, since in more consolidated theories (such as physics), matter is assumed to have quite different properties (matter is neither homogeneous nor continuous, and is isotropic in just some cases). In contrast, from the perspective of the model-based and representational view of theories, it is possible to say that strength of materials proposes representational models about some systems of the world, and that systems can be considered to have the properties of homogeneity, continuity, and isomorphism. That is to say, different purposes can bring about the generation of different models. Margaret Morrison (Morrison 1999) and Paul Teller (Teller 2001) have studied the case of water: how water can be considered to be either a collection of molecules (when the diffusion of a drop of ink in a glass of water is analyzed); or a fluid (to analyze the behavior of water circulating in pipes). In other words, there can be multiple models dealing with the same phenomena, if those models deal with different properties of phenomena, and the purposes for analyzing are also different. Reality is too complex to be grasped with only one theory. Theories are sets of models that search for characterizations or explanations of the behavior of some systems that are nothing but partial aspects of reality. In this sense, strength of materials is doing nothing different. The only difference has to do with the purposes of the research.[31] The following sections discuss this issue in greater detail.

4.2. Types of models utilized.

As Giere has pointed out (1999b), it is possible to distinguish between different types of representational models: (i) *material models,* among which he includes maps, diagrams, and scale models; (ii) *abstract models,* such as pure mathematical models, applied mathematical models, and theoretical models built with theoretical principles (such as Newton's laws, Schroedinger's equation for quantum mechanics, Darwin's theory of natural selection, and Mendel's laws of genetics). All these models can be used to build scientific theories, including strength of materials, as is shown next.

In the case of strength of materials, the authors abstract basic forms of materials.[32] Basic forms are presented using *graphic models* of machines and structures. The structures can be separated into parts that fit one of the four basic forms of the theory. The graphic models are limited and can only be considered to represent those characteristics of real objects that permit engineers to design workable artifacts. The models should not be assumed to also represent characteristics of real objects. The models are context-dependent (Giere 1999b, 4).

The central aspects of the theory deal with two idealized aspects of forces, being understood as strains, or internal forces, and loads, or external forces. Authors use plane cross-sections, graphic idealized models of how forces work, to illustrate the differences between the various internal forces. Plane cross sections are found in every textbook and are quite helpful for understanding the *mathematical model* provided to account for different strains. Numerous examples are used to illustrate this general model.

The core of strength of materials deals with the relationship between strain, stress, and deformation. *Pure mathematical models* about the forces show the relationship between strain and stress and deformation of bodies. Hooke's law defines the relationships between strain, stress and deformation. First, the law is explained in simple mathematical form, and afterwards as a generalized set of fundamental equations (sets of mathematical models). Hooke's law behaves as a *general principle,* that is, *it is used to build models about different loads and deformations of materials and structures.* The authors of all of the textbooks show how the law behaves with standard materials using many examples.

The next chapters deal with the construction of models using Hooke's law, taking into account different loads relevant to engineers' purposes. Textbooks analyze idealized or pure forms of the application of loads, which are torsion, tension, and deflection. It is important to distinguish between dynamic or static loads because these different loads lead to different *pure mathematical models.* It is also relevant if dynamic loads are continuously repeated, because this can cause fatigue of materials that lead to breaks. All these models are built upon Hooke's law, and have a great number of practical design applications.

Since loads do not usually act alone, but in conjunction with different forces inherent to structures and machines, textbooks propose *main models* to account for different combinatory possibilities. In terms of the theory's purposes, these models are still *excessively idealized.* Strength of materials has to facilitate the construction of real designs, and these designs have to fulfill some verification and safety criteria. Engineers must be cautious, because materials are not perfectly homogeneous, are affected by fatigue, and are degradable. The last parts of these books are devoted to analyzing the real conditions and environmental pressures, in which materials and structures must work. Taking these real conditions into account, the authors of the textbooks propose — from abstract mathematical models — *applied mathematical models,* with more detailed factors of correction.

Presentations of strength of materials in the different textbooks incorporate all of Giere's models. The main principle of strength of materials, Hooke's law, is the basis for many of the models. At the same time, it is possible to point out an important difference between Giere's characterization of the natural sciences and the engineering theory analyzed in this paper: strength of materials calls for applied mathematical models rather than the more abstract models found in natural scientific theories. This is the first point at which strength of materials significantly diverges from other scientific theories.[33] Mathematical models are usually presented in their pure form and rarely with correction factors. Strength of materials is directed toward the construction of safe and effective artifacts. This practical purpose turns out to be a factor of the greatest importance in order to establish the extent of similarity between models and systems of the world.

4.3. Similarity between models and the world.

The concept of similarity is one of the most controversial of Giere's proposals. On the one hand, some critics have pointed out that it is necessary to show how one model, which is an abstract phenomenon, can be "similar" to a particular object in the world. Teller (2001, 399) gives an answer to this question: similarity does not take place between different ontological categories, but between properties of models and properties of specific systems.

There is still another problem related to the reasons why scientists prefer a specific model. According to Giere, scientists, generally speaking, prefer models that represent those aspects of reality in the most accurate way that they consider relevant to their purposes. Scientists select the appropriate model through experiment (Giere 1999a, 53). Nevertheless, somebody could argue that this is not a convincing criterion from which to establish the extent of similarity between one model and one system in the world. The phenomena that scientists usually handle in experiments do not naturally occur, but these facts are artificially produced and confined to special conditions in the laboratory. Even so, experiments can be reproduced in a controlled manner by different scientists in different laboratories, without any modification of the results.[34]

Giere maintains that scientists do not make decisions as if they were Bayesian agents, nor do they behave as "satisficers," as Herbert Simon holds (1945). If scientists are rational agents, then it is necessary to admit that scientists pursue the achievement of some goals. Thus, the more efficient a scientist's method, the more rational it can be considered (Giere 1988, 160; also 1999a, 82). In other words, scientists' rationality is "conditional" or "instrumental," since scientists behave rationally when propounding the model that better fits with reality.[35]

4.4. Reasons for choosing one model in strength of materials.

For sake of the argument, let's agree that strength of materials could be characterized in terms of a cluster of different kinds of models. It could be interesting to determine if there are some differences between the goals pursued by basic scientists and engineering-scientists when they are building their respective models. In the case of strength of materials, the main desired objective of engineers developing the theory is to put forward theoretical and mathematical models which can be useful in order to design safe, lasting and efficient artifacts. In the case of "basic" sciences, the main goal is to know how things are, that is, suggest models that represent and explain accurately some interesting aspects of reality. Those different goals will determine differences in the attributes considered valuable in both cases. As Ernan McMullin has pointed out:

> A property or a set of properties may count as a value in an entity of a particular kind because it is desirable for an entity of that kind. (The same property in a different entity might not count as a value.) […]The desirable property is an objective characteristic of the entity. We can thus call it a characteristic value. In some cases, it is relative to a pattern of human ends; in others, it is not. In some cases, a characteristic value is a means to an end served by the entity possessing it; in others, it is not. In all cases, it serves to make its possessor function better as an entity of that kind" (McMullin 1982, 5).

During the last decades, some philosophers have been trying to put forward a list of desirable attributes by different sciences.[36] So far, there has not been agreement on a particular set of principles, and other problems arise. First, as Kuhn pointed out (1977, 331), different scientists may evaluate differently the attributes of a particular theory. There is no algorithm for an assessment of this kind, so it will depend on the individual scientist's training, experience, and goals. Second, "scientists may not attach the same relative weights to different characteristic values of theory; that is, they may not value the characteristics in the same way, when, for example, consistency is to be weighed over against predictive accuracy. It is above all because theory has more than one criterion to satisfy, and because the 'valuings' given these criteria by different scientists may greatly differ, that disagreement in regard to the merits of rival theories can on occasion be so intractable" (McMullin 1982, 16). One theory, hypothesis, or model can be empirically adequate but not very simple, or can be simple but not very explanatory, and so on… which is why scientists need to weigh up these attributes and determine which model is the best one among different possibilities.

In order to do that, scientists could behave as Bayesian maximizers, or as Simon's satisficers. Nevertheless, both of these alternatives have some problems, as Giere has pointed out (Giere 1988, 145-165; see also Giere 1969 against the application of game theory to decisions related to hypotheses). Alex Michalos (1970) suggested another solution that can be more realistic than the other ones. Michalos' proposal evaluates the costs and benefits of choosing a hypothesis (or a model in our terms), and takes into account the different desirable characteristics that scientists can expect in a model. In Michalos' terms, a decision maker has to choose between different possible and mutually exclusive hypotheses, trying to elucidate which one is *the most adequate for his interests*. In order to make this decision, the decision maker has to determine the "raw forms" of the benefits and costs attached to each combination.

> For example, he must be able to determine whether two hypotheses are equally explanatory or one explains more than the other; he must be able to rank order any three distinct levels of explanatory power transitively; and he must recognize that his preferences ought to prefer a hypothesis that explains more phenomena to one that explains less (if all other things are equal) (Michalos 1970, 64).

Among benefits, the decision maker can take into account such things as "explanatory power, simplicity, coherence with other theories, precision, etc." (Michalos 1970, 64). And costs will be such things as "required set-up time, computational effort, special facilities, technical assistance, money, operationalization, etc." (Michalos 1970, 65). In general terms, a model is better than its alternatives depending on the benefits and costs of accepting it.[37] Scientists will choose between attributes that they consider especially relevant.

"For our purposes it is not necessary to reach an agreement on the optimal set of appraising attributes" (Michalos 1970, 74). There is a tendency for decision-makers to assess some attributes as more important than others in order to determine their final judgment. The reasons for doing that will depend on the general purposes that scientists have to consider in order to generate models. In the case of strength of materials, when engineer-scientists have to propound the best model for their goals, they need to weigh up the benefits and costs of the available models, and they, like any other scientist, will prefer those models with more benefits and less costs. The main difference between engineer-scientists and scientists in basic areas are the benefits that they consider more important to fulfill, as well as the costs that they try to avoid.

A criticism against this suggestion could be that it mixes up some values commonly considered as epistemic and others that are commonly considered pragmatic. Nevertheless, as Duhem, Popper, or Carnap made clear a long time ago, the borderline between pragmatic and epistemic values may be difficult to draw, since pragmatic reasons are as important as epistemic ones in scientific development. In this sense, instead of differentiating the attributes between epistemic and pragmatic, perhaps it could be more suitable to refer to them as values (as a desirable property) or non-values (as a non desirable property).

4.5. Desirable attributes for strength of materials.

Engineer-scientists' models have to fulfill some values in order to represent some aspects of reality in the most accurate way considered relevant for engineers' purposes. In order to decide which model is the best (with more desirable attributes), engineers can apply the general principle of costs and benefits, referred to now as desirable and non-desirable attributes. Let's analyze some of the most important attributes that models have to fulfill for the purposes of strength of materials.

(1) Internal consistency: Every scientific theory has to be consistent from an internal point of view. From the same principles it cannot be possible to infer A and ¬A. If strength of materials were not internally consistent, then the suggested equations would provide contradictory conclusions, and the artifacts built would be inefficient, and non-safe.

(2) Empirical adequacy: Strength of materials models have to be adequate with respect to the empirical facts. Despite the fact that the models are not isomorphic

with reality, they try to explain some observable properties of materials. Sometimes, the empirical adequacy of strength of materials is not the same as that provided by theoretical models from basic sciences. The reason for this contradictory feature is the different properties both sciences are trying to analyze. Strength of materials analyzes the effects of loads on the internal structure of bodies. From physicists' point of view, all bodies are perfectly rigid, and the shape of bodies does not change under the action of external loads. These deformations do not affect the general laws of equilibrium or the motion of bodies; that is why they are not taken into account in theoretical mechanics. Nevertheless, bodies do change, but these deformations are so small that physicists can abstract from them (transforming them into *ceteris paribus* clauses), because they do not affect the general laws of equilibrium and the movement of bodies. But, as a matter of fact, all the shapes of material bodies change when they are subjected to external loads, something that must be acknowledged in order to build safe constructions.

Strength of materials models simplify and abstract other properties in an unacceptable way from the point of view of basic sciences. For instance, materials are considered as *homogeneous and continuous* despite the well known fact that no materials are actually homogeneous because of their molecular composition. Materials are usually considered *isotropic*, something that is not true for every material. However, from the point of view of engineering sciences materials behave as if they were homogeneous, continuous, and isotropic.

(3) Accuracy: Strength of materials models, instead of generating accurate values about the behavior of bodies, create sets of limit values, among which decisions must be made.

When different loads are studied, examples at different points are analyzed in order to know how the loads affect a wide range of materials with different shapes. Engineers commonly use security coefficients when applying the models to real building instances. When the real behavior of materials and bodies with different shapes is not accurately known, and the law can only provide with some approximation, then some maximum and minimum safe values are offered.

(4) Fruitfulness: From a relatively small set of theoretical principles (stress, strain, load, Hooke's law, Saint-Venant's principle…), engineers who develop strength of materials equations try to suggest a range of specific models. Strength of materials models have to be fruitful in order to generate an adequate

comprehension of the behavior of different materials. That is the reason why strength of materials calls for applied mathematical models rather than the more abstract models found in natural scientific theories, and why experimental work is done on different kinds of materials and body shapes.[38]

(5) Explanatory power: Strength of materials models have to be explanatory with respect to some properties of materials. Models must be explanatory in the sense of generating general principles that correctly characterize the behavior of the materials. That is the case, for instance, of Hooke's law or Saint-Venant's principle. Some philosophers have considered explanatory power as the main goal in scientific activity. Nevertheless, those who develop engineering sciences need to bear in mind the practical goal of their activity. That is, engineering theories have to be explanatory in order to be useful for designing artifacts.

(6) Prediction of surprising results: Strength of materials models, instead of predicting surprising results, try to avoid the emergence of this kind of outcomes when models are used generating artifacts. In some sense, it could be said that those surprising non-desired results are foreseen; at least an attempt is made to foresee them. The risk of building a failed artifact can involve an unacceptable cost.[39]

To approve a hypothesis or model as a basis for a specific kind of action is an important desirable feature in engineering sciences. Some philosophers would argue that this is not part of theoretical science, strictly speaking.[40] That could be true for those theories that are not conceived with a practical goal in mind, theories that could or could not be applied in the future. The difference here is that the main concern for basic scientific models is to explain with generality, whereas the main concern for engineering scientific models is to be useful in some phase of designing artifacts. The applicability is a desired attribute, and the risks of applying an unsafe model cannot be run.

(7) Novelty: There are "models or theories that differ in significant ways from presently accepted theories, either by postulating different entities and processes, adopting different principles of explanation, incorporating alternative metaphors, or by attempting to describe and explain phenomena that have not previously been the subject of scientific investigation" (Longino 1996, 45). Strength of materials models differ in significant ways from physics models, postulating different entities and characteristics, such as homogeneity and continuity of material, and processes, as well as different stresses and strains that different

bodies can bear without deforming. Thus, models of strength of materials describe and explain phenomena that had not previously been the subject of scientific investigation. Moreover, those models make possible investigations during the production of new materials, and the application of generated knowledge to new artifacts, another sense of novelty.

(8) Ontological heterogeneity: "A theory characterized by ontological heterogeneity (or ontological diversity) is one that grants parity to different kinds of entities"(Longino 1996, 46). This attribute is fulfilled in strength of materials models. As mentioned in the earlier discussion about empirical adequacy, strength of materials researchers do not only suggest models about materials in general, but about specific materials and for specific shapes of them, in different temperatures and load conditions.

(9) Applicability to current human affairs: This kind of attribute is essential for engineering science models, and in many senses it conditions other desirable attributes. For instance, empirical adequacy can be understood as regarding different properties of matter not considered relevant for basic sciences; accuracy can be proposed within a range (or spectrum) of different safe possibilities instead of looking for idealized and abstract values, or the outcome of *ceteris paribus* clauses inappropriate for the applicability purposes of strength of materials; surprising results have to be avoided, because the by-product risk of building a failed artifact can involve an unacceptable cost; the kind of phenomena that are interesting from a strength of materials models point of view are more heterogeneous than the kind of phenomena that are interesting from a basic sciences point of view; that is, the ontology is more heterogeneous for the engineering sciences because different materials behave in very different ways, something that must be known in order to build artifacts with them. In other words, the main concern of strength of materials models is to solve problems arising during designing activities, and to open up new possibilities.

The search for applicability also determines some attributes, otherwise described by philosophers as necessarily desirable, to become less important for strength of materials models. For instance:

(1) Simplicity: Strength of materials models could give up simplicity, and ontological heterogeneity, for applicability to current human affairs, a more desirable attribute from the engineer's point of view.

(2) External consistency: Strength of materials models are proposed in spite of their inconsistency with models from well established basic sciences. Engineers can overlook external inconsistencies with physics, because they result from basic simplifications and idealizations regarding the relevant properties that different sciences try to analyze.

(3) Scope: Strength of materials models can renounce breadth of scope for models that fulfill the aim of ontological heterogeneity. In order to accomplish breadth of scope, basic scientists may need to use *ceteris paribus* clauses that avoid the heterogeneity and dynamic aspects of the real world. But this tactic is used (carefully) in strength of materials models, because engineers who develop and use theoretical or mathematical models need to apply them to real situations and they need to avoid surprising (or catastrophic) results.

Disparities between the desirable values in strength of materials and desirable values in the basic sciences depend on the goals that engineers and basic scientists have to fulfill when developing their models. The way that engineers weigh desirable values decides some features of their models. Generally speaking, engineering sciences are part of a complex technological system, whose main goal is not to know how things are (typical on a scientific system), but to build useful artifacts. Applicability to current human affairs is the main goal pursued by engineers, and it yields different ways of weighing the costs and benefits of suggested models. If there are differences between engineering science models and basic science models they will be found in the evaluation of desirable attributes; in the final analysis, in their differing goals.

Conclusions

Defining technology as applied science underestimates the complex nature of technology. Technology demands knowledge that does not come from traditional scientific theories. Not every scientific theory can be applied to obtain technological developments. There are many scientific results, and not all of them have technological applications. Even though some natural scientific theories are applied to technological purposes, the process of applying scientific theories to produce technological devices (given technological complexity nowadays) has never been satisfactorily explained. Nonetheless, it is plausible to think that there must be theoretical science knowledge involved in contemporary technology.

This paper has tried to suggest some good reasons why engineering sciences can be included in the scientific category. It is possible to offer a characterization of the engineering sciences using an explanation originally proposed for natural scientific theories. Engineering sciences have, nevertheless, a significant difference: those who have developed these technological theories are engineers, and from the constructivist point of view it could be said that the attributes that their models have to fulfill (attributes they consider desirable) could be different from desirable attributes in basic science models.

With the aim of illustrating this, the case of strength of materials has been analyzed. The features of this engineering theory have been examined using Giere's semantic and model-based frame. The theory can be understood as a cluster of models that represent, with different degrees of similarity, different aspects of reality. The main differences between basic scientific theories and strength of materials are based on the purposes of the engineers who develop the theory and who use it afterwards. In general, it is possible to say that scientists' main purpose is "to know how things are," whereas engineers developing strength of materials would add "in order to make other things work."

A final caveat: Some critics could claim that the use of cost-benefit analysis as a criterion for choosing between different models could lead to an instrumentalist point of view of scientific theories; the relevance of models depends on their capability for fulfilling different benefits determined "in a raw form" by scientists. Does this imply relativism? I do not think so. Defenders of relativistic positions about scientific theories can maintain that, as with any other human creation, scientific theories have no more than a relative value. However, from the perspective suggested in this paper, scientists develop models in order to achieve goals. If there is any rationality when scientists develop a best model, a model that better fits with reality, it has to be a conditional or instrumental rationality. Engineers also have to develop a best model, and so they use an instrumental rationality considering their purposes. However, the differences between these purposes lead to differences between the values (or desirable attributes) which are to be fulfilled by the models; and that is the main difference between engineering science models and basic science models.

This approach could be used to analyze other technological theories. Paul T. Durbin thinks so and uses it to understand genetic engineering (see Durbin 2005), and the author of this article seeks to apply the approach to Artificial Intelligence, specifically to mobile robotics. Of course, every cluster of models will show peculiar features, but all engineering science models share the necessity of combining two purposes: “to understand” and to do so “in order to create technological artifacts.”

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[1] The author of the article is non-native English speaker. For this reason, she would like to ask for forgiveness for those errors and mistakes she could commit writing the article.

[2] Pitt 2000; Radder 1996.

[3] Giere, 1988, 1992, 1993, 1994, 1999a, 1999b, 2002, forthcoming (1), and forthcoming (2).

[4] We also could include here T. Kortabinski, H. Rumpf, G. Ropohl and others, but the cited authors are representative of the main ideas on the subject.

[5] See Constant, 1980.

[6] Just to mention a classic: "Science as an institutionalized art of inquiry has yielded varied fruit. Its currently best-published products are undoubtedly the technological skills that have been transforming traditional forms of human economy at an accelerating rate." (Nagel 1961, vii). In the same vein we could see too the "miracle argument" by J. J. C. Smart, 1963 and Hilary Putnam, 1975.

A more recent contribution is Radder's view: "Concerning experimental natural science as such, I think two legitimations play a fairly prominent and general role. The first is the claim that science is valuable because it delivers the truth about nature or, at least, promises to eventually give a true account of nature. The second major social legitimations is framed in the claim that experimental science is practically useful, that its results can often be fruitfully incorporated into all kinds of technological projects. (…) Actually, in present-day society, the "technological" legitimations seems to be the most influential." (Radder 1996, 40).

[7] For a broader explanation and discussion: A. Chakravartty 2001.

[8] For a historical review: Suppe 1989.

[9] For instance: Giere 1988, 92.

[10] He deliberately says that the natural laws are not universal, nor necessaries, nor truth. (Giere 1999, 90).

[11] These ideas derive from pragmatism (Giere 1999, 75). In philosophy of technology we could find something similar in: Pitt 2000, 4.

[12] For instance: Giere 1999a, 180.

[13] He agrees with N. Cartwright (1983, 11), "No single model serves all purposes best." (Also in p. 104 and 152). "Imagine the universe as having a definite structure, but exceedingly complex, so complex that no models humans can devise could ever capture more than limited aspects of the total complexity. Nevertheless, some ways of constructing models of the world do provide resources for capturing some aspects of the world more or less well. Other ways may provide resources for capturing other aspects more or less well. Both ways, however, may capture some aspects of the reality and thus be candidates for a realistic understanding of the world. So here, in principle, is a solution to the problem of finding a picture of science that is both naturalistic and realistic." (Giere 1999a, 79).

[14] Against the idea that "much engineering knowledge is 'cookbook engineering'." (Pitt 2000, 38).

[15] I have decided to use several textbooks from different periods instead of only one in order to avoid a biased presentation.

[16] This is not the same as defending that these theories are inferior from the point of view of their epistemological features.

[17] This supposition is adopted despite the well known fact that no material can really be homogeneous because of their molecular composition. Moreover, the textbooks later analyze materials' fragility and the homogeneity supposition will be questioned.

[18] Actually, this characteristic does not correspond with real properties of most materials. Every crystal is no isotropic, but if the body contains great deal of chaotically oriented crystals it can be considered as isotropic.

[19] In some textbooks, instead of four, one can find three basic forms. In these cases it is supposed that vaults are special types of plates.

[20] "The internal forces must be distributed over the section that the deformed surfaces of the section A are a perfect fit when the right and the left portions of the body are brought together.

In strength of materials and in the theory of elasticity this condition is known as the condition of continuity of deformations." (Feodosiev 1968, 2s).

[21] "The purpose of the analysis is to decide whether or not the structure meets the requirements of reliability" (Feodosiev 1968, 31).

[22] Robert Hooke, curator of the Royal Society, originally laid down this principle in 1679, saying "ut tensio, sic vis."

[23] (Stepin 1963, 114) Shafts, spindles of turning lathes, and jackhammers and other pieces work with torsion (Pisarenko et al. 1975, 7-8).

[24] Many elements of structures work by tension or compression, framework beams, columns, shoot of piston machines, bolts for tightening…etc. (Pisarenko et al. 1975, 7-8).

[25] Instances of deflection are beams of intermediate flats, of bridges, axis in train coaches, springs, shafts, gear teeth, wheels' spokes, levers, etc. (Pisarenko et al. 1975, 7-8).

[26] "The objective of strength of materials is not only to reveal the inherent features of phenomena but also to provide background for the correct interpretation of the laws so obtained in the assessment of efficiency and serviceability of the structure under consideration." (Feodosiev 1968, 14).

[27] Willems, Easley, Rolfe 1981, 385.

[28] Engineers often make a lengthy use of their textbooks because they can use these useful tables in their professional life when designing concrete artifacts.

[29] This is certainly and extremely abbreviated account, just the minimum to present the theory in some textbooks. Of course, every one who is interested in other details should read the cited textbooks.

[30] Ronald Laymon has worked on this matter. See, for instance: Laymon 1989, 1991.

[31] This idea is suggested by Giere, Morrison, and Teller, although neither of them apply it to the case of engineering sciences.

[32] In some texts the basic forms are four, and in others three. In this case, vaults are considered as special cases of plates.

[33] "The margins of error rarely appear in the descriptions or calculations until one gets to the point of comparing theoretical predictions with actual measurements. This practice strongly supports interpreting the original equations without explicit margins of error, as referring not to actual things but to abstract models of which they are true by definition." (Giere 1999b, 6).

[34] Radder examines three types of reproducibility in experimental practice: (i) Reproducing the material realization, (ii) Replication of the experimental result, and (iii)

reproducing under a fixed theoretical description. (1996, 20-28). Lange analyzes different ways of knowledge acquisition in order to do reproducible experiments: "Communication and cooperation ensure the synchronomous extensibility of experimental practice in space, specialist education ensures their diachronous persistence." (2003, 133)

[35] However, this is not the only motive used to choose among models. As a matter of fact, Giere claims "what is essential is that scientists have other interests as well, and that these play a significant role in scientific decisions. As I understand it, a cognitive theory of the science need not deny the importance of these other interests. If it did it, it could not be an adequate theory of science." (Giere 1988, 165).

[36] Thomas S. Kuhn (1977) discusses five features that scientist use choosing between theories: accuracy, consistency (both internal and with other relevant currently accepted theories), scope (its consequences should extend beyond the data it is required to explain), simplicity (organizing otherwise confused and isolated phenomena), and fruitfulness (for further research). Helen Longino (1990) distinguishes between constitutive and contextual values, being the constitutive ones: empirical adequacy, simplicity, and explanatory power. Larry Laudan (1990) points out another catalog of characteristics: internal consistency, the prediction of surprising results, and variety of evidence. Paul Churchland (1985) identifies simplicity and explanatory power as cognitive or epistemic virtues that enable us to go beyond mere empirical adequacy. Longino (1996) reveals a feminist's set of desiderata in scientific theories: empirical adequacy, novelty, ontological heterogeneity, mutuality of interaction, applicability to current human needs, and diffusion of power.

[37] "If for every possible contingency and for every attribute, the benefits and costs of accepting one hypothesis are preferable (i. e., ought to be preferred) to those of accepting another, then the former *strongly dominates* the latter. If for some contingency and for some attribute, the benefits and costs of accepting one hypothesis are preferable to those of another and for all the remaining contingencies and attributes the benefits and costs of accepting the latter are not preferable to those of the former, then the former dominates the latter." (Michalos 1970, 65)

[38] "As we have already noted, the introduction of iron and steel into structural and mechanical engineering made experimental study of the mechanical properties of those materials essential. Earlier experimenters had usually confined their attention to determining ultimate strengths, but it was now realized that the properties of iron and steel depend upon the technological processes involved in manufacture and that, in any case, a knowledge of ultimate strength only is insufficient when selecting a suitable material for a particular purpose. A more thorough investigation of the mechanical properties of materials became of utmost practical importance. Such tests require special equipment, and we shall see that in the period under consideration a rapid growth of material-testing laboratories took place in many countries." (Timoshenko 1953, 276)

[39] As Richard Rudner argued about the acceptance of a scientific hypothesis: "Is going to be a function of the importance, in the typically ethical sense of making a mistake in accepting or rejecting the hypothesis. Thus, to take a crude but easily manageable example, if the hypothesis under consideration were to the effect that a toxic ingredient of a drug was not present in the lethal quantity, we would require a relatively high degree of confirmation or confidence before accepting the hypothesis, for the consequences of making a mistake here are exceedingly grave by our moral standards." (Rudner 1953, 2) Related to engineering sciences, this kind of analysis is of a great relevance.

[40] "If theory is being applied to practical ends, and the theoretical alternatives carry with them outcomes of different value to the agents concerned, we have the typical decision-theoretic grid involving not only likelihood estimates but also "utilities" of one sort or another. Such utilities are irrelevant to theoretical science proper and the scientist is not called upon to make value-judgments in their regard as part of his scientific world." (McMullin 1982, 8).

Artefacts and Collective Intentionality

Seumas Miller
Seumas.Miller@anu.edu.au
Centre for Applied Philosophy and Public Ethics
(An Australian Research Council Funded Special Research Centre)
Charles Stuart University
Australian National University
University of Melbourne

Social reality is multifaceted and comprises at least social conventions and norms, social roles and relations, social institutions and social artefacts. John Searle's ambitious project in his *Construction of Social Reality* is to show in general terms how social reality can be accommodated to physical reality (Searle 1995). This raises a host of issues including how individual mentality and sociality are to be related, and how sociality and morality are to be related. Elsewhere I have argued against Searle's anti-individualist conception of sui generis 'we-intentions' (Miller 2001, ch. 2). Specifically, I have argued in favour of what I term the collective end account of joint action according to which sui generis 'we-intentions' are neither desirable nor necessary. I have also suggested that Searle's constructivist collective acceptance account of social forms emasculates central moral notions such as that of right and duty. On Searle's account, human rights and correlative moral duties, for example, can exist only by virtue of collective acceptance of specific practices. Accordingly, in morally degenerate societies in which human rights are never respected, we must conclude that there simply are no human rights to be respected, for we have no external moral standpoint from which to make moral judgements in relation to collectively accepted social practices.

Searle's account can also be assessed in terms of its adequacy at the level of more specific social forms, such as social artefacts and social institutions. Elsewhere I have argued against Searle's account of social institutions and in favour of my own teleological account (Miller 2001, ch. 6). In this paper I want to consider Searle's account of social artefacts. The social artefact category has a number of sub-categories, including technical objects. Technical objects are such things as screwdrivers, levers and the like, as opposed to coins, sceptres and such. (The latter might be termed "institutional artefacts" for reasons explained below.) I argue against Searle's account of social artefacts. Moreover, I suggest that his general account is not well suited for the analysis of a number of sub-categories of social artefacts, including technical objects and institutional artefacts. I draw on my earlier work and also that of Peter Kroes in his paper "Screwdriver Philosophy: Searle's Analysis of Technical Functions" (Kroes 2003).

Artefacts and Functions

Artefacts such as chairs, tables, screwdrivers, levers, hammers, coins and so on are humanly designed and constructed physical objects that have certain functions. Their physical size, shape etc. have been designed so that they can be used for certain purposes. Accordingly, they have interacted *causally* with human beings and with other elements of the physical world at two stages, namely the stage of design and the stage of use. The screwdriver has been fashioned out of (say) wood and metal, and thus has been given a certain shape and size etc.. Moreover, a screwdriver is an implement that carpenters and others use to drive in and extract screws which are themselves artefacts that enable, for example, bits of wood to be held together tightly and in a stable manner. So artefacts include not only designed physical objects that causally mediate human agents and elements of the physical world that are not artefacts, many artefacts also mediate between human agents and other artefacts.

Naturally, there are objects, e.g., logs, which can be used as (say) chairs, but have not been designed as such. As Kroes points out, these involve cases of accidental as opposed to proper functions (Kroes 2003, 8). Accordingly, objects with proper functions are not only used to bring about purposes, they have been designed to serve those purposes. The properties of the physical object are designed in such a way that their causal powers are in the service of the human agents who use them.

This designed-in feature of artefacts also serves to distinguish artefacts from physical objects that are simply used to serve human purposes, but that do not have a function as such, e.g., trees that are cut down and used as fuel.

It is consistent with the above to hold that some token of an artefact type is an artefact notwithstanding the fact that the token has never in fact been used. On the other hand, if no tokens of a given design type have ever in fact been used because, contra their designer, there is in fact no use for them, then they are not really artefacts, or at least not paradigms of artefacts, but rather, say, mere ornaments.

The first general point to be made here is that in the paradigm case, at least, artefacts – in the sense of technical objects such as screwdrivers - have been *causally acted on* by human agents in the design phase, and in the use phase artefacts are both *acted on* and themselves *causally efficacious* in processes involving human agents bringing about certain outcomes. Specifically, in using an artefact an agent acts on an artefact, e.g., a screwdriver, in such a way as to cause the artefact in turn to cause an outcome, e.g., an extracted screw. Moreover, the designers and users of artefacts impose intentionality on artefacts in the sense, firstly, that the shape, size and other physical properties of an artefact have been *intentionally* brought about. Secondly, when artefacts are causally bringing about the outcome that they were designed to bring about this causal process is *intended*.

However, when Searle talks of artefacts and other social objects having intentionality imposed upon them he means that the fact that some physical object is an artefact, e.g., a screwdriver, is an observer-relative feature of the world. This seems to be either false or trivial. For the imposition of intentionality involved in artefacts is not necessarily that involved in standard cases of observer-relative phenomena, such as, say, visual perception; if someone 'sees' a red light when almost everyone else 'sees' a green light then – notwithstanding that the light is green – the person is having a visual experience of a red light. But just because the members of a hippie community under the influence of drugs sees what is in fact an ice cream cone as a screwdriver does not make it one. Nor for the same reason is it observer relative in the sense of relativism, i.e.: If A believes that p then p. The ice cream cone has not been designed to be and cannot be used as a screwdriver, notwithstanding the false beliefs of the members of the hippie community.

Given this standard sense of the term "observer-relative," Searle would be taken to be claiming that beliefs and other cognitive states are a sufficient condition for being an artefact. As we have seen, this is clearly false. Kroes suggests that Searle, rather, intends to be claiming that such intentional states are merely a *necessary* condition for being an artefact. However, even this is doubtful, if the intentional states in question are the states of passive observers, as opposed to the states of causally active agents, i.e. if the states are beliefs, or other like cognitive states, as opposed to, say, intentions.

Suppose Robinson Crusoe designs and constructs an entirely new implement to break open coconuts, but falsely believes that the object is incapable of functioning as such; after years without being rescued Crusoe has become an incurable pessimist. Now suppose Man Friday finds the implement and tries to break open coconuts. In fact, Friday succeeds in opening the coconuts. However, under the influence of hallucinogenic drugs provided by Crusoe to ease the pain of social isolation, Friday believes that he never actually succeeds in opening any coconut. This implement is in fact an artefact, and has been designed and is used as such; but is not believed by anyone to be an artefact. The general point is that artefacts are not necessarily *believed* to be such; and so artefacts are not observer-relative in the sense that their being artefacts is dependent on someone believing them to be so.

On the other hand, artefacts necessarily involve human *intentions*. Artefacts are a primary locus of human agent causation. As such, the intentional dimension of artefacts is only observer-relative in the trivial sense that the intentions manifest in their design and use are, qua intentions, subjective states.

The second general point is that there appears to be a distinction between social and non-social artefacts. Doubtless, artefacts are in the paradigm case social objects. However, if Robinson Crusoe designs and uses a completely new device for breaking open coconuts, the Crusoe Coconut opener, and the device is never replicated or used or even known about by anyone else, then presumably the device is not a social object, though it is clearly an artefact.

The third general point is that in order for artefacts – in the sense of technical objects – to be used successfully to achieve the outcomes for which they were designed, they have to have a number of properties, including properties relative to the outcome they are used to bring about, and relative to the agents who are to use them. Thus a screwdriver has to have a certain shape and size, if it is to be able to extract screws of a given shape and size. But it also has to have a certain size and shape, albeit within a range of possible sizes and shapes, if it is to be used by humans with hands of a certain size and shape, as opposed to, say, intelligent animals with huge tentacles but no hands.

Artefacts and Physical Objects

An important question arising here – and discussed by Kroes – concerns the necessity or sufficiency or otherwise of physical properties, as opposed to intentional properties, for something to be an artefact (technical object). Kroes convincingly argues that Searle's analysis oscillates between defining artefacts in terms of their imposed intentionality and doing so in terms of those of their physical properties that enable them to be used as artefacts. Is an artefact a physical object different from other physical objects only in so far as it has intentionality externally imposed on it, e.g., a log used as a seat is an artefact, but one which is not so used is not a seat? Or is an artefact a physical object that has a set of physical properties that enable it to be used in various ways, even if it is in fact not so used? Such sets of physical properties may or may not have been designed-in.

If Searle is taken to be claiming that artefacts are simply physical objects whose properties enable them to be used in the service of human purposes then his definition is far too weak. Almost any physical object could be used for some human purpose. The very ground beneath us can be used as a seat; trees are chopped up, burned and used as fuel to heat us. Rocks could be used as parts of the walls of houses. However, none of these physical objects is an artefact.

Moreover, the definition of artefacts in terms of useable physical objects is inadequate for making out a distinction between artefacts in the sense of technical objects, and artefacts of other kinds, e.g., coins and the crowns of kings.

Nor will recourse to Searle's notion of the imposition of collective intentionality deal with this problem.[i] For if screwdrivers and chairs are physical objects upon which functions have been collectively imposed, so are coins and the crowns of kings.

As Kroes points out, the definition of artefacts requires recourse to both sets of properties, i.e., physical properties and intentions; however, the difficulty lies in spelling out the precise relationship between them.

Without attempting to provide an adequate full-blown account of artefacts, I think the following is a serviceable definition for my purposes here. In the paradigm case, artefacts are physical objects whose physical property set has been designed by members of a social group to be used by agents in that group to achieve certain outcomes, and they are so used. Such paradigm cases include what might be regarded as non-institutional artefacts such as screwdrivers (technical objects), as well as institutional artefacts such as coins.

The distinction between institutional and non-institutional artefacts is problematic, especially given that both institutional and non-institutional artefacts have both a physical and an intentional dimension. However, my suggestion is that the distinction can be made out in terms of the different purposes or functions of these two categories of artefact. Roughly speaking, non-institutional artefacts, such as screwdrivers, have as their purpose or function to bring about changes in the physical world, e.g., to bring it about that screws are driven in or extracted. By contrast, institutional artefacts qua institutional artefacts have as their purpose or function to bring about changes in the institutional world, e.g., to bring it about that person A now *owns* the product he exchanged his coins for.

Status-Functions[ii]

According to Searle, institutional facts, including facts about institutional artefacts such as coins, are (ultimately) facts about physical objects, or states of affairs or events, upon which, what he terms, status-functions have been collectively imposed (Searle 1995, 41). I say "ultimately" because although status-functions can be collectively imposed on pre-existing institutional facts, any such iterated structure of status-functions must terminate at some point in physical objects or events (or more precisely, must terminate in what he terms, brute facts) (Searle 1995, 27, 34).

Something has a status- function if it has, or those who use it have, deontic powers. Thus a police officer has a status-function, and therefore a set of deontic powers, including rights to stop, search and arrest people under certain conditions. A five-dollar bill is a piece of paper (a physical object) the bearers of which have various deontic powers, including the right to exchange the bill for goods to the value of five dollars. These status-functions, and therefore deontic powers, have been collectively imposed in the sense that the relevant members of a community accept or agree to or otherwise treat the objects or persons that possess these status-powers as if they do in fact possess them. But in accepting or so treating, for example, the police officer as if he has the right to arrest people, the police officer comes to have that right. By Searle's lights, if no one ever paid any attention to police officers they would cease to have any deontic powers and therefore any status-function; indeed they would cease to be police officers. Similarly, if no one were prepared to exchange five-dollar bills for goods then these bits of paper would cease to have any status-function, and the bearers of them would cease to have any deontic powers.

Searle's account makes use of four basic notions: (1) imposition of functions; (2) the deontic powers of institutional persons and objects; (3) the distinction between constitutive and regulative rules; (4) collective intentionality.[iii] Let us look more closely at these notions, beginning with functions and deontic powers.

Functions and Deontic Powers

Searle's notion of function concerns what it is that an individual (individually) or a group (collectively) imposes on a physical phenomenon. For example, if members of a community began to sit on a log then the log would in effect have become a bench. So a function – that of being used to sit on – would have been collectively imposed on a physical object. However, as we saw above, Kroes has pointed out that logs and the like are not artefacts in the paradigm sense of technical objects. For example, artefacts are designed rather than simply having a function individually or collectively imposed upon them by way of being used.

On Searle's conception all functions ultimately depend on the existence of physical objects on which functions are imposed. However, some functions – such as the function of being a chair – depend on the *specific* physical properties of the object on which they are imposed. Thus a log can become a bench only if it has a certain size and shape; giant redwood trunks are not serviceable as seats. By contrast, a key feature of *institutional* facts is that they involve functions that are not able to be imposed simply by virtue of the specific physical properties of the phenomena on which they are imposed. Rather possession of the function exists by virtue of the *collective* character of the imposition (Searle 1995, 39). So being a chair is not an institutional fact; rather, its functionality exists by virtue of its specific physical properties. On the other hand, being a medium of exchange is an institutional fact; its functionality supposedly exists by virtue of collective imposition rather than specific physical properties.

It should be noted that according to Searle functions can be individually imposed on physical objects by individuals. This would be the case if, for example, Robinson Crusoe alone used the log as a bench. Further, if a log had the function of a bench *collectively* imposed on it, then its being a bench would be a social fact (Searle 1995, 88). However, the fact that the log was a bench would not be an *institutional* fact; for its being a bench does not depend on the *collective* character of the imposition of this function.

Here we should reiterate that in the case of artefacts at least, the physical properties themselves have been individually or collectively imposed viz. in the design phase. Moreover, the above-mentioned way of drawing the distinction between institutional and non-institutional artefacts is problematic since both chairs and coins are physical objects and not just any physical object could be a chair or a coin. Moreover, both chairs and coins are designed and used by collectives; so both involve collective imposition. However, in the case of non-institutional artefacts typically the physical properties need to be relatively specific. But why is this so?

Presumably this is because the outcome that they are intended to bring about, e.g. extracting a screw, is a purely physical outcome. Such artefacts need to have specific physical properties because of the nature of their function. By contrast, institutional artefacts, such as coins, typically do not need to have specific physical properties. Here it is a matter of degree. A set of large buildings could not serve as coinage. But why is there this latitude in the case of institutional artefacts? Presumably because the function of institutional artefacts is to bring about institutional changes, e.g., ownership. But why should this entail greater latitude? Perhaps because there is greater latitude in the design of institutions. Arguably, the purposes that institutions serve are more open-ended and vague than the purposes served by artefacts. But from this is does not obviously follow that there is great latitude in the design of institutional *artefacts* – as opposed to the design of the institutions themselves.

Following Searle, perhaps institutional artefacts invariably have a symbolic dimension, since institutional change necessarily involves communication, and institutional artefacts necessarily have a communicative function as part of their overall function. Certainly, there is great latitude in the choice of symbols. However, institutional artefacts have other non-symbolic functions in addition to their symbolic function. So the question arises as to whether or not these non-symbolic functions confer latitude in the design of institutional artefacts. Consider coins. Their principal function is to be used as a medium of exchange. But this purpose could be served by a wide variety of physical objects, so designers have considerable latitude in the design of mediums of exchange. On the other hand, coins need to be reasonably lightweight and durable, if they are to serve their purpose. So the latitude in their design is not all that great. Moreover, the designers of some non-institutional artefacts, such as tables and chairs, also have considerable latitude.

A further point here is that many non-institutional artefacts have a symbolic dimension, e.g., expensive dining tables. So it is by no means clear that the symbolic dimension of institutional artefacts is what explains the apparently greater levels of latitude that exist in the case of institutional, but not non-institutional artefacts.

Ultimately, Searle intends to rely on his conception of status functions with deontic powers to distinguish between institutional and non-institutional facts, including artefacts. Accordingly, says Searle, what makes a physical object, such as a piece of metal or paper, a dollar coin or dollar note, i.e., an institutional artefact, is not its physical properties but rather collective imposition of that status function and associated deontic powers.

According to Searle, in the case of institutional facts the imposition of a function consists not only in the assignment of a function, but also of a status with deontic properties (Searle 1995, 100-1). These deontic properties – rights and duties and the like – are regarded by Searle as powers. If a police officer has a right to arrest you, then he has a power to do so; if you have a right to goods worth five dollars in exchange for your five-dollar bill, then you have a power to receive those goods. And to reiterate, these status functions or powers are possessed by virtue of the agreement or acceptance of the community; the powers are collectively imposed and maintained.

The tight connection that Searle makes between function imposition and deontic properties is problematic. Searle asserts that the notion of a function necessarily brings with it values and deontology. Thus if the purpose of the heart is to pump blood, then it ought to pump blood (Searle 1995, 15-6, 19). No doubt, purposes and ends can be assessed in the sense that they can be said to have been realised or to have failed to be realised. Moreover, if one has an end, then, other things being equal, one ought to enact the means to that end. So functions, goals and the like bring with them normativity in the minimal sense of the normativity of instrumental rationality. But the claim that functions and purposes bring with them normativity in any stronger sense has not been shown. Specifically, Searle has not shown that his deontic properties, such as rights and duties, can be derived from the notion of a function. Nor has he shown that deontic properties can be derived from his notion of function taken in conjunction with collective intentionality. Indeed, it would seem that his own examples of tool using social animals is sufficient to demonstrate that deontology is not generated by functionality, whether collectively imposed or not.

A more plausible source of *some* deontic properties is rules in the sense of explicitly formulated directives issued by authorities to perform certain kind of actions under certain circumstances. However, Searle claims that 'rules' in the very general sense of *general policies* can be abused, and hence have a normative status (Searle 1995, 48). As I have argued elsewhere, I do not accept the proposition that general policies or habits necessarily generate *standards* of conduct – as opposed to mere regularities in behaviour – and therefore deontic properties. Certainly Searle offers no demonstration of his claim.

At any rate, I suggest that it is a non sequitur to move from individual or collective imposition of functional properties to deontic properties. For it is perfectly possible for a person or an object to have a set of functions – and be treated as having those functions – without any associated (non-instrumental) deontology. For example, a set of individuals might use a certain sort of relatively rare shell as a medium of exchange, and do so notwithstanding the fact that no-one had any desire to possess these shells independent of the fact that they could be used as a medium of exchange. In this scenario all that is required is that each exchange shells for goods, and goods for shells, intend to continue to do so, and believe that all the others do and intend likewise. Of course it would add greatly to the stability of this arrangement if these shells were somehow authorised as an official medium of exchange, and if a (rule constituted) system of rights and duties in relation to the exchange of these shells was introduced and enforced. However, such a deontological structure is not a necessary feature of the system of exchange.[iv] Here we have artefacts and imposition of collective intentionality, yet there are no deontic powers, and hence (arguably) no institutional artefacts.

Moreover, even where a deontological framework of the kind described by Searle has been adopted, the relevant deontic powers do not subsume, take the place of, provide the basis for, or go hand in hand with, the substantive functions of the objects or persons in question. Here by *substantive* functions I mean the functions that are *central* and necessary to the object or person being the kind of thing that it is. Consider an incompetent surgeon who is incapable of performing a successful operation on anybody, and who largely avoids doing so, or when he absolutely has to, always ensures that he is part of a team comprised of other competent surgeons and nurses who actually do the work. By virtue of being a fully accredited surgeon this person has a set of deontic powers, including the right to perform surgery, and others have deontic powers in relation to him, including the right that he performs operations competently and with due diligence. Moreover, these deontic powers are maintained in part by (say) the Royal College of Surgeons, his colleagues and the community. However, the surgeon simply does not possess the substantive functions of a surgeon. The deontology is there but the substantive functionality is not. Accordingly, it is simply false to claim, as Searle must do, that he is a surgeon (Searle 1995, 49-50).[v] If someone cannot perform, and knows nothing about, surgery, he cannot be a surgeon, irrespective of whether he has the highest professional qualification there is, is treated as if he were a surgeon, and indeed is widely believed to be the finest surgeon in the land.

Now consider a currency that has been devalued by virtue of, say, a collapse in the economy, so that notwithstanding government declarations, very few are prepared to exchange goods for the official currency; the currency has official status, but has largely gone out of use. So the currency has deontic powers underpinned by the government, but no longer has substantive functionality. Accordingly, deontic powers are at best a *necessary* condition for being an institutional artefact.

I conclude that in relation to institutional facts, including artefacts, Searle's notion of deontic power – whether collectively imposed or not – does not necessarily subsume, take the place of, provide the basis for, or go hand in hand with, substantive functionality. In the case of artefacts, as well as institutional roles, substantive functionality and deontic powers can come apart; there can be substantive functionality without deontic powers, and deontic powers without substantive functionality. However, institutional artefacts and institutional role cannot simply be defined in terms of deontic powers. For if there is no substantive functionality then there is no artefact, institutional or otherwise, and if there is no substantive functionality there is no institutional role. Thus deontic powers are at best a necessary condition for being an institutional artefact.

Let us turn now to Searle's notion of collective intentionality, and the related notions of social acceptance and social agreement.

Collective Intentionality, Collective Acceptance and Constitutive Rules

Searle's apparatus of status-functions is created and sustained by what he terms collective intentionality. As we have just seen, his view that the substantive functions of objects and persons is subsumed by, or necessarily goes hand in hand with, deontic powers is incorrect. Moreover, it is now clear that collective intentionality cannot generate the substantive functions of many institutional artefacts and persons. What of the relationship between collective intentionality and deontic powers? Let us get a little clearer on the notion of collective intentionality.

Collective intentionality is for Searle a primitive notion expressed by locutions such as "we-intend." A we-intention is not reducible to an individual intention, nor to an individual intention in conjunction with other individual attitudes such as individual beliefs (Searle 1995, 24-6). It will be evident from my discussion in the opening section of this paper that I do not accept Searle's conception of primitive we-intentions. I take the view that an analysis is possible using only individualistic notions, including especially the above-mentioned notion of a collective end. In any case Searle's notion of primitive we-intentionality is under-theorised. He has not provided an account of it, analytical or otherwise.

But that aside, what of the role of collective intentionality – however it is to be understood – in relation to the creation and maintenance of deontic powers? Consider the deontic powers associated with the utterance of sentences, such as the right of hearers that speakers will aim at the truth. Searle must hold that such a right can only exist if a group adopts some sort of we-attitude, e.g., we-accept or we-agree or we-belief or we-intention, to these deontic powers. And presumably the same goes for other moral rights that may attach to artefacts, such as intellectual property rights in relation to inventions or cultural rights in relation to social artefacts created by a particular social group such as the Australian aborigines. In the latter case if the larger Australian community does not accept or we-agree to the contemporary minority aboriginal population having custody and other rights to ancient indigenous artefacts, does it follow that there are no such moral rights?

Arguably all humans have a right to life,[vi] hearers have a moral *right* that speakers aim at the truth, and individual and group 'inventors' of artefacts have intellectual and cultural property rights to those artefacts. Moreover these moral rights exist quite independently of whether the larger community in which those individuals or groups live we-intends that this be the case, or accepts that it is, or whatever. So the *source* of at least some central deontic properties, namely, some moral properties, is evidently not collective intentionality.

Naturally, whether or not deontic properties, including rights, are *respected* might ultimately turn on the attitude of the community. So general community 'acceptance' of deontic properties, including rights – in a weak sense of acceptance – is necessary for the *maintenance* of the deontological framework in that community. So much is trivially true.[vii]

I conclude that Searle has not established that all or most deontic properties associated with institutional artefacts and persons are (so to speak) *ontologically* dependent on collective intentionality (Searle 1995, 104).[viii]

I now want to focus attention on the connection between collective acceptance and substantive functionality. I will begin with the special case of institutional authorities.

What is it to collectively accept or collectively treat someone as if he or she is a leader? Presumably it is for people to obey her directives because they believe that they ought to do so. But now what is the actual or realised substantive functionality of a leader? Surely it is in large part getting people to obey one's directives because they believe that they ought to do so. So in the case of leaders, and other institutional authorities, I suggest that Searle's notion of collective acceptance is redundant; it collapses into actual or realised substantive functionality. To possess the functional properties of a leader is (in large part) to have one's directives obeyed by one's followers. But to have one's directives obeyed by one's followers is to be collectively accepted.

What of the relation of collective acceptance and substantive functionality in the case of institutional artefacts, e.g., coins or notes. Once again I suggest that Searle's notion of collective acceptance collapses into the actual or realised substantive functionality of the institution.[ix] If people exchange dollar notes for the purpose or end of receiving goods (and exchange goods for the purpose of receiving dollars) then they have 'accepted' dollars in the only important sense of that term; so there is no need for an additional notion of collective intentionality or collective acceptance or treating dollars as if they were dollars.

And there is this further point. Persons using social artefacts, including as a medium of exchange, typically act in conformity with conventions, and indeed, social norms. So the substantive functionality of these institutions is realised in accordance with conventions and social norms. Accordingly, there is collective acceptance in the sense of conformity to conventions and social norms. When we use a medium of exchange we typically do so in part by conforming to the relevant conventions and social norms. So much is obvious.

A final point about Searle's notion of collective intentionality and its relation to rules: In his later formulations it turns out that the we-intentional state in question is conventional in character; he speaks of conventional powers (Searle 1995, 104). Searle nowhere offers an analysis of conventions. However, he does distinguish them from rules. For Searle, conventions, by contrast with rules, are arbitrary (Searle 1995, 28). Moreover, as we saw above, he takes the view that rules are necessarily normative phenomena.

There are a number of unanswered questions here. What exactly is the nature of rules and conventions, and precisely how are these phenomena to be differentiated?

While Searle does not explain the nature of conventions or the nature of rules in general, he does offer an account of the distinction between constitutive rules and regulative rules. Moreover, constitutive rules have a key role in his account of institutions. Unlike regulative rules, constitutive rules "create the possibility of certain activities" (Searle 1995, 28). Constitutive rules have the form 'X counts as Y in C' where Y is the function imposed on X in conditions C (Searle 1995, 28). So constitutive rules are, according to Searle, very important in the construction of social institutions and institutional artefacts.

Now it is by no means clear that some *conventions* could not have the form "X counts as Y in C'. On Searle's view of conventions as arbitrary, a convention-governed imposition of Y on X (if it were possible) would necessarily be a matter of arbitrary choice. But this seems to be so in many instances. Consider a convention among military strategists to use certain shaped pebbles to stand for troops in their strategising concerning troop movements.

More important, it is by no means clear that the notion of a *rule* – as opposed to a certain realised rule *content* viz. that persons count something as something else – is actually doing any work here. I argued above that function imposition does not necessarily bring with it values and deontology. Now I suggest that function 'imposition,' whether collective or not, does not require rules, or even conventions. Consider the above-mentioned example of military strategists collectively imposing functions on physical objects. If they used toy soldiers that looked like real soldiers then the arbitrary character of their decision would diminish. So by Searle's lights there would not be a convention. But equally there might be no rule. It might be a one-off episode, never to be repeated. The point is that it is the notion of counting one thing as another thing that is doing the work; whether they count x as y in accordance with a convention or rule or by virtue of some other collective device is not important.

This latter point is really a special case of the more general point made earlier, namely, that collective acceptance collapses into actual or realised substantive functionality. For what is critical is that the relevant individuals perform the action – viz., count the pebble as a soldier, use the paper as a medium of exchange, and so on. What is critical is not constitutive rules, but rather substantive functionality.[x]

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[i] For an account of collective intention and related notions see Miller, *Social Action* Chapters 1 and 2.

[ii] An earlier version of much of the material on Searle on institutions – as opposed to artefacts - in the following sections appeared in Miller op.cit. Chapter 6.

[iii] Searle ascribes a certain priority to the institution of language - language is somehow constitutive of institutional reality. Searle *Construction of Social Reality* chapter 3. Searle account of institutions also involves, what he calls, background abilities. ibid. chapter 6.

[iv] Searle in a later paper ("Reply to Raimo Tuomela" *Philosophy and Phenomenological Research* 57, no 2 1997) claims that the point of the deontic power is to enable the performance of the function. But the function of money viz. exchange can be performed by shells (without deontic status), and the function of surgeons by non-accredited persons with surgery skills. That is, it is false that deontic powers are necessary for the performance of these functions.

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[v] Searle oscillates between claiming that there is a collective imposition of substantive functionality and claiming (in effect) that there is a collective imposition of *additional, ancillary* deontic powers. I do not dispute the latter.

[vi] As Immanuel Kant pointed out, the right to life underpins all other rights, since it is a necessary condition for their enjoyment.

[viii] In Searle's terms, "the Y content is imposed on the X element by collective acceptance."

[ix] Raimo Tuomela makes a similar point in his "Searle on Social Institutions" *Philosophy and Phenomenological Research* 57 no 2, p2.

[x] Thanks to anonymous referees from *Techné* for criticisms of an earlier draft of this paper.

The Epistemology of Technological Risk

Sven Ove Hansson
soh@kth.se
Department of Philosophy and the History of Technology,
Royal Institute of Technology
Stockholm, Sweden

1. Introduction

Beginning in the late 1960's, growing public concern with new technologies gave rise to a new field of applied science: the study of risk. Researchers from the technological, natural, behavioural, and social sciences joined to create a new interdisciplinary subject, risk analysis. (Otway 1987) The aim of this discipline is to produce as exact knowledge as possible about risks. Such knowledge is much in demand, not least among managers, regulators, and others who decide on the choice and use of technologies.

But to what extent can risks be known? Risks are always connected to lack of knowledge. If we know for certain that there will be an explosion in a factory, then there is no reason for us to talk about that explosion as a risk. Similarly, if we know that no explosion will take place, then there is no reason either to talk about risk. What we refer to as a risk of explosion is a situation in which it is not known whether or not an explosion will take place. In this sense, knowledge about risk is knowledge about the unknown. It is therefore a quite problematic type of knowledge.

2. Risk as a quantitative concept

Although many have tried to make the concept of risk as objective as possible, on a fundamental level it is an essentially value-laden concept. More precisely, it is negatively value-laden. Risks are unwanted phenomena. The tourist who hopes for a sunny week talks about the "risk" of rain, but the farmer whose crops are threatened by drought will refer to the possibility of rain as a "chance" rather than a "risk."

There are more distinctions to be made. The word “risk” is used in many senses, that are often not sufficiently distinguished between. Let us consider four of the most common ones.

(1) risk = an *unwanted event* which may or may not occur.

This is how we use the word “risk” when we say that lung cancer is one of the major risks that affect smokers, or that aeroembolism is a serious risk in deep-sea diving.

However, we may also describe smoking as a (health) risk or tell a diver that going below 30 meters is a risk not worth taking. We then use the word “risk” to denote the event that caused the unwanted event, rather than the unwanted event itself:

(2) risk = the *cause* of an unwanted event which may or may not occur.

In addition to identifying the risks, i.e. finding out what they are, we also want to determine how big they are. This is usually done by assigning to each risk a numerical value that indicates its size or seriousness. The numerical value most often used for this purpose is the probability of the event in question

Indeed, risks are so strongly associated with probabilities that we often use the word “risk” to denote the probability of an unwanted event rather than that event itself. This terminology is particularly common in engineering applications. When a bridge-builder discusses the risk that a bridge will collapse, or an electrical engineer investigates the risk of power failure, they are almost sure to use “risk” as a synonym of probability.

(3) risk = the *probability* of an unwanted event which may or may not occur.

As should be clear from the three definitions presented thus far, the word “risk” is a very versatile – and ambiguous – one. Consider a situation in which the probability is 10% that a certain person will contract lung cancer due to smoking. We can then use the word “risk” to denote either the cancer, the act of smoking, or the 10% probability.

It is important to note that probability, and hence risk in the third sense, always refers to a specified event or type of event. If you know the probability (risk) of power failure, this does not mean that you have a total overview of the possible negative events (risks) associated with the electrical system. There may be other such events, such as fires, electrical accidents etc., each with their own probabilities. In risk analysis, a concept of risk has been developed that aims at quantifying the total amount of risk associated with a technological system:

(4) risk = the statistical *expectation value* of unwanted events which may or may not occur.

Expectation value means probability-weighted value. Hence, if 200 deep-sea divers perform an operation in which the individual risk of death is 0.1% for each individual, then the expected number of fatalities from this operation is 200 x 0.1% = 0.2.

Expectation values have the important property of being additive, i.e. they can be added. Suppose that a certain operation is associated with a 1% probability of an accident that will kill five persons, and also with a 2% probability of another type of accident that will kill one person. Then the total expectation value is 0.01x5 + 0.02x1 = 0.07 deaths. In similar fashion, the expected number of deaths from a nuclear power plant is equal to the sum of the expectation values for each of the various types of accidents that can occur in the plant. (Bondi 1985, p. 9) The following is a typical example of the jargon:

> The worst reactor-meltdown accident normally considered, which causes 50 000 deaths and has a probability of 10^{-8}/reactor-year, contributes only about two per cent of the average health effects of reactor accidents. (Cohen 1985, 1)

In risk-benefit analysis, i.e. the systematic comparison of risks with benefits, risks are measured in terms of their expectation values. This is also the standard meaning of risk in several branches of risk research. Hence, in studies of risk perception the standard approach is to is to compare the degree of severity that subjects assign to different risk factors ("subjective risk") to the expectation values that have been calculated for the same risk factors ("objective risk"). The underlying assumption is that there is an objective, knowable risk level that can be calculated with the expectation value method.

However, this measure of risk is problematic for at least two fundamental reasons. First, probability-weighing is normatively controversial. A risk of 1 in

1000 that 1000 persons will die is very different from a risk of 1 in 10 that 10 persons will die. Although the expectation values are the same, moral reasons can be given to regard one of these two situations as more serious than the other. In particular, proponents of a precautionary approach maintain that prevention against large but improbable accidents should be given a higher priority than what would ensue from an expectation value analysis. (O'Riordan and Cameron 1994, O'Riordan et al 2001)

The other problem with the expectation value approach is that it assesses risks only according to their probabilities and the severity of their consequences. Most people's appraisals of risks are influenced by factors other than these. In particular, the expectation value method treats risks as impersonal entities, and pays no attention to how risks and benefits are distributed or connected. In contrast, the relations between the persons affected by risks and benefits are important in most people's appraisals of risks. It makes a difference if it is myself or someone else that I expose to a certain danger in order to earn myself a fortune. If the expectation value is the same in both cases, we can arguably say that the size of the risk is the same in both cases. It does not follow, however, that the risk is equally acceptable in the two cases. More generally speaking, if we use expectation values to measure the size of risks, this must be done with the reservation that the size of a risk is not all that we need to in order to judge whether or not it can be accepted. Additional information about its social context is also needed.

3. The tuxedo syndrome

From a decision-maker's point of view, it is useful to have risks quantified so that they can easily be compared and prioritized. But to what extent can quantification be achieved without distorting the true nature of the risks involved?

As we have just seen, probabilities are needed for both of the common types of quantification of risk (the third and fourth senses of risk). Without probabilities, established practices for quantifying risks cannot be used. Therefore, the crucial issue in the quantification of risk is the determination of probabilities.

Not all dangers come with probabilities assigned to them. In decision theory, the terms "risk" and "uncertainty" are used to distinguish between those that do and those that do not. By a decision "under risk" is meant a decision with known or knowable probabilities. By a decision "under uncertainty" is meant one that has to be taken with unknown probabilities. In one of the most influential textbooks in decision theory, the terms are defined as follows:

> We shall say that we are in the realm of decision-making under:
> (a) *Certainty* if each action is known to lead invariably to a specific outcome (the words prospect, stimulus, alternative, etc., are also used).
> (b) *Risk* if each action leads to one of a set of possible specific outcomes, each outcome occurring with a known probability. The probabilities are assumed to be known to the decision maker. For example, an action might lead to this risky outcome: a reward of $10 if a 'fair' coin comes up heads, and a loss of $5 if it comes up tails. Of course, certainty is a degenerate case of risk where the probabilities are 0 and 1.
> (c) *Uncertainty* if either action or both has as its consequence a set of possible specific outcomes, but where the probabilities of these outcomes are completely unknown or are not even meaningful. (Luce and Raiffa 1957, p. 13)

This usage of the key terms "risk" and "uncertainty" differs distinctly from everyday usage. In everyday conversations, we would not hesitate to call a danger a risk although there are no means to determine its probability. By uncertainty we would mean a state of mind rather than the absence of information. However, these are well-established technical terms, and in what follows, they will be used in their standard technical meanings.

The gambler's decisions at the roulette table are clear examples of decisions under risk, i.e. decisions with known probabilities. Given that the wheel is fair, the probabilities of various outcomes – gains and losses – are easily calculable, and thus knowable, although the gambler may not take them into account. For a clear example of a decision under uncertainty, consider instead the decision of an explorer to enter a distant part of the jungle, previously untrod by human foot. There are tigers and poisonous snakes in the jungle, but no estimates better than guesses can be given of the probability of being attacked by them. Such attacks are known dangers with unknown probabilities. In addition, it is reasonable to expect that the jungle contains a large number of other species – from microorganisms to large animals – some of which may be dangerous although they are completely unknown. Not only their probabilities but their very existence is unknown. (Unknown dangers are not included in Luce and Raiffa's definition of uncertainty, as quoted above, but in subsequent discussions the concept of uncertainty has been extended to include them.)

In real life we are seldom in a situation like that at the roulette table, when all probabilities are known with certainty (or at least beyond reasonable doubt). Most of the time we have to deal with dangers without knowing their probabilities, and often we do not even know what dangers we have ahead of us. This is true not least in the development of new technologies. The social and environmental effects of a new technology can seldom be fully grasped beforehand, and there is often considerable uncertainty with respect to the dangers that it may give rise to. (Porter 1991)

Risk analysis has, however, a strong tendency towards quantification. Risk analysts often exhibit the *tuxedo syndrome*: they proceed as if decisions on technologies were made under conditions analogous to gambling at the roulette table. In actual fact, however, these decisions have more in common with entering an unexplored jungle. The tuxedo syndrome is dangerous since it may lead to an illusion of control. Risk analysts and those whom they advice may believe that they know what the risks are and how big they are, when in fact they do not.

4. Unknown probabilities

When there is statistically sufficient experience of an event-type, such as a machine failure, then we can determine its probability by collecting and analysing that experience. Hence, if we want to know the probability that the airbag in a certain make of car fails to release in a collision, we should collect statistics from the accidents in which such cars were involved.

For new and untested technologies this method is not available. Due to the lack of accident statistics, it cannot be used to determine the probability of airbag failure in a new car model that is just to be introduced. If the construction is essentially unchanged since previous models, then we may rely on statistics from these earlier models, but this is not advisable if there have been significant changes.

Even after many years' experience of a technology there may be insufficient data to determine the frequencies of unusual types of accidents or failures. As one example of this, there have (fortunately) been too few severe accidents in nuclear reactors to make it possible to estimate their probabilities. In particular, most of the reactor types in use have never been involved in any serious accident. It is therefore not possible to determine the risk (probability) of a severe accident in a specified type of reactor.

One common way to evade these difficulties is to calculate the probability of major failures by means of a careful investigation of the various chains of events that may lead to such failures. By combining the probabilities of various subevents in such a chain, a total probability of a serious accident can be calculated. Such calculations were in vogue in the 1970's and 1980's, but today there is a growing skepticism against them, due to several difficult problems with this methodology. One such problem is that accidents can happen in more ways than we can think of beforehand. There is no method by which we can identify all chains of events that may lead to a major accident in a nuclear reactor, or any other complex technological system.

Another problem with this methodology is that the probability of a chain of events can be very difficult to determine even if we know the probability of each individual event. Suppose for instance that an accident will happen if two safety valves both fail. Furthermore suppose that we have experience showing that the probability is 1 in 500 that a valve of this construction will fail during a period of one year. Can we then conclude that the probability that both will fail in that period is 1/500 x 1/500, i.e. 1/25000? Unfortunately not, since this calculation is based on the assumption that failures in the two valves are completely independent events. It is easy to think of ways in which they may be dependent: Faulty maintenance may affect them both. They may both fail at high temperatures or in other extreme conditions caused by a failure in some other component, etc. It is in practice impossible to identify all such dependencies and determine their effects on the combined event-chain.

In spite of these difficulties, the construction and analysis of such event chains (often called fault-trees) is not a useless exercise. To the contrary, this can be an efficient way to identify weaknesses in a complex technological system. It is important, though, to keep in mind that an exhaustive list of negative events cannot be obtained, and that therefore total risk levels cannot be determined in this way.

Technological risks depend not only on the behaviour of technological components, but also on human behaviour. Hence, the risks in a nuclear reactor depend on how the personnel act both under normal and extreme conditions. Similarly, risks in road traffic depend to a large degree on the behaviour of motorists. It would indeed be difficult to find an example of a technological system in which failure rates depend exclusively on its technical components, with no influence from human agency. The risks associated with one and the same technology can differ drastically between organizations with different attitudes to risk and safety. This is one of the reasons why human behaviour is even more difficult to predict than the behaviour of technical components.

Humans come into probability estimates in one more way: It is humans who make these estimates. Unfortunately, psychological studies indicate that we have a tendency to be overly confident in our own probability estimates. In other words, we tend to neglect the possibility that our own estimates may be incorrect. It is not known what influence this bias may have on risk analysis, but it certainly has a potential to create errors in the analysis. (Lichtenstein 1982, 331) It is essential, for this and other reasons, to make a clear distinction between those probability values that originate in experts' estimates and those that are known through observed frequencies.

5. Unknown dangers

There are occasions when decisions are influenced by worries about possible dangers although we have only a vague idea about what these dangers might look like. Recent debates on biotechnology are an example of this. Specific, identified risks have had only a limited role in these debates. Instead, the focus has been on vague or unknown dangers such as the creation of new life-forms with unforeseeable properties.

It is easy to find examples in which many of us would be swayed by considerations of unknown dangers. Suppose, for instance, that someone proposes the introduction of a genetically altered species of earthworm that will aerate the soil more efficiently. If introduced in nature, it will ultimately replace the common earthworm. For the sake of argument we may assume that all concrete worries have been neutralized. The new species can be shown not to induce more soil erosion, not to be more susceptible to diseases, etc. Still, it would not be irrational to say: "Yes, but there may be other negative effects that we have not been able to think of. Therefore, the new species should not be introduced." Similarly, if someone proposed to eject a chemical substance into the stratosphere for some good purpose or other, it would not be irrational to oppose this proposal solely on the ground that it may have unforeseeable consequences, and this even if all specified worries can be neutralized.

However, it would not be feasible to take such possibilities into account in all decisions that we make. In a sense, *any* decision may have catastrophic unforeseen consequences. If far-reaching indirect effects are taken into account, then – given the unpredictable nature of actual causation – almost any decision may lead to a disaster. In order to be able to decide and act, we therefore have to disregard many of the more remote possibilities. Cases can also easily be found in which it was an advantage that far-fetched dangers were not taken seriously. One case in point is the false alarm on so-called polywater, an alleged polymeric form of water. In 1969, the prestigious scientific journal *Nature* printed a letter that warned against producing polywater. The substance might "grow at the expense of normal water under any conditions found in the environment," thus replacing all natural water on earth and destroying all life on this planet. (Donahoe 1969) Soon afterwards, it was shown that polywater is a non-existent entity. If the warning had been heeded, then no attempts would had been made to replicate the polywater experiments, and we might still not have known that polywater does not exist. In cases like this, appeals to the possibility of unknown dangers may stop investigations and thus prevent scientific and technological progress.

We therefore need criteria to determine when the possibility of unknown dangers should be taken seriously and when it can be neglected. This problem cannot be solved with probability calculus or other exact mathematical methods. The best that we can hope for is a set of informal criteria that can be used to support intuitive judgement. The following list of four criteria has been proposed for this purpose. (Hansson 1996)

> *1. Asymmetry of uncertainty*: Possibly, a decision to build a second bridge between Sweden and Denmark will lead through some unforeseeable causal chain to a nuclear war. Possibly, it is the other way around so that a decision not to build such a bridge will lead to a nuclear war. We have no reason why one or the other of these two causal chains should be more probable, or otherwise more worthy of our attention, than the other. On the other hand, the introduction of a new species of earthworm is connected with much more uncertainty than the option not to introduce the new species. Such asymmetry is a necessary but

insufficient condition for taking the issue of unknown dangers into serious consideration.

2. *Novelty*: Unknown dangers come mainly from new and untested phenomena. The emission of a new substance into the stratosphere constitutes a qualitative novelty, whereas the construction of a new bridge does not.

An interesting example of the novelty factor can be found in particle physics. Before new and more powerful particle accelerators have been built, physicists have sometimes feared that the new levels of energy might generate a new phase of matter that accretes every atom of the earth. The decision to regard these and similar fears as groundless has been based on observations showing that the earth is already under constant bombardment from outer space of particles with the same or higher energies. (Ruthen 1993)

3. Spatial and temporal limitations: If the effects of a proposed measure are known to be limited in space or time, then these limitations reduce the urgency of the possible unknown effects associated with the measure. The absence of such limitations contributes to the severity of many ecological problems, such as global emissions and the spread of chemically stable pesticides.

4. Interference with complex systems in balance: Complex systems such as ecosystems and the atmospheric system are known to have reached some type of balance, which may be impossible to restore after a major disturbance. Due to this irreversibility, uncontrolled interference with such systems is connected with a high degree of uncertainty. (Arguably, the same can be said of uncontrolled interference with economic systems; this is an argument for piecemeal rather than drastic economic reforms.)

It might be argued that we do not know that these systems can resist even minor perturbations. If causation is chaotic, then for all that we know, a minor modification of the liturgy of the Church of England may trigger a major ecological disaster in Africa. If we assume that all cause-effect relationships are chaotic, then the very idea of planning and taking precautions seems to lose its meaning. However, such a world-view would leave us entirely without guidance, even in situations when we consider ourselves well-informed. Fortunately, experience does not bear out this pessimistic worldview. Accumulated experience and theoretical reflection strongly indicate that certain types of influences on ecological systems can be withstood, whereas others cannot. The same applies to technological, economic, social, and political systems, although our knowledge about their resilience towards various disturbances has not been sufficiently systematized.

6. The role of experts

The distinction between risk and uncertainty relates to the epistemic situation of the individual person. If you are absolutely certain that current estimates of the effects of low-dose radiation are accurate, then decision-making referring to such exposure may appear to you as decision-making under risk. On the other hand, if you are less than fully convinced, then such a decision will have the characteristics of decision-making under uncertainty. Even when exact estimates of risk are available, to the extent that there is uncertainty about these estimates, there is also uncertainty involved in the decision.

The exact estimates of risks that are available in some fields of knowledge have in general been made by highly specialized experts. If these experts have full confidence in their own conclusions, then decisions based on these estimates are, from their own point of view, decisions under risk (known probabilities). However, the situation may look different from the viewpoints of managers, other decision-makers, and the general public. Experts are known to have made mistakes. A rational decision-maker should take into account the possibility that this may happen again. Suppose for instance that a group of experts have studied the possibility that a new micro-organism that has been developed for therapeutical purposes will mutate and become virulent. They have concluded that the probability that this will happen is 1 in 100 000 000. For the decision-makers who receive this report the crucial issue need not be whether or not a risk of that magnitude should be accepted. Instead it could be how certain the conclusion is.

Insufficient attention has been paid in risk management to the fallibility of experts. Experts often do not realize that for the non-expert, the possibility of the experts being wrong may very well be a dominant part of the risk (in the informal sense of the word) involved e.g. in the use of a complex technology. On some (but not all) occasions when experts have complained about the public's irrational attitude to risks, the real difference is that the public has focused on uncertainties, whereas experts have focused on quantified risk estimates.

Clearly, when there is a wide divergence between the views of experts and those of the public, this is a sign of failure in the social system for division of intellectual labour. Such failures have not been uncommon in issues of technological risks. However, it should not be taken for granted that every such failure is located within the minds of the non-experts who distrust the experts. It cannot be a criterion of rationality that experts are taken for infallible. Other issues must be raised, such as whether or not experts have been able to deal satisfactorily with the concerns of the public.

7. Conclusion

We started out by noting that knowledge about risk has a mildly paradoxical flavour, since it is knowledge about the unknown. We have indeed found severe limitations in what knowledge can be obtained about technological risks. Technology is associated not only with quantifiable risks but also with non-quantifiable uncertainties that may be quite difficult to come to grips with. Unexpected events do happen, not least in technological systems.

For the engineer, this insight has important practical consequences. Even if risk estimates show that a fire in the plant is so improbable that sprinklers are uneconomical, it may be a good idea to install those sprinklers, since there may be unknown causes of fire that have not been included in the calculations. Even if a toxic gas is so well contained that the possibility of a leakage has been virtually excluded, measures should be taken to protect workers and others who may be affected in the (unlikely) event of a leakage.

This is, of course, not a new insight, but rather epistemological underpinnings for well-established principles in safety engineering, such as contingency planning and redundant safety barriers. Safety does not mean measures only against those hazards that are known and quantified, but also, as far as possible, against those that are unknown and unexpected.

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Genetic Engineering: the unnatural argument

Anne Chapman
Institute for Environment, Philosophy and Public Policy
Lancaster University

Introduction

The assertion that genetic engineering is wrong because it is unnatural strikes a chord with many people and, I think, encapsulates why they have a gut reaction against the technology. However, it is dismissed by regulators and many philosophers (eg. Straughan 1999), because they fail to examine how 'unnatural' and 'natural' are actually used in the context of technological practices. Instead, they focus on one or both of the two principal meanings of 'nature' given by John Stuart Mill (Mill 1904): nature is "the collective name for everything which is," in which case we cannot do anything that is unnatural; or "it is everything which is of itself, without voluntary human intervention," from which it follows that everything we do in a planned, considered way is unnatural. In contrast to these two meanings people do actually regard some technological products or practices as being more natural than others: organic farming is considered more natural than 'conventional' agriculture; wool, cotton and silk are 'natural' fibres whereas acrylic and polyester are not, and one particular technique for avoiding conception is termed 'natural birth-control' whereas the contraceptive pill would never be called 'natural.' Rather than dismissing such terminology as the product of romantic ignorance, I would like to pay attention to what 'unnatural' and 'natural' mean in these contexts. This I will do by considering the characteristics of the three sets of technologies mentioned above. I will then argue that genetic engineering can be said to be unnatural and put forward three reasons why the unnaturalness of a technology makes it morally suspect.

Natural and unnatural technologies

Natural methods of birth control involve the woman coming to understand when she is fertile and avoiding sexual intercourse during that period of her menstrual cycle. Human behaviour adapts itself to nature in order to achieve the outcome that the human desires. In contrast, the contraceptive pill interferes with the woman's menstrual cycle so that she can have intercourse at any time of the month without getting pregnant. Rather than human behaviour, nature (the woman's body) is modified and changed.

The term "natural fibres" refers to materials such as wool, cotton or linen which are produced by animals or plants and prepared for use by human action, as opposed to synthetic fibres such as nylon and polyester, which are synthesised from simple chemicals in industrial processes. The production of "raw" natural fibres depends on the processes of living nature: the fibre-providing animals or plants grow by their own organic process; humans simply try to ensure that the necessary conditions are available for this to happen. I say "try" because in fact many of the necessary conditions are not under human command: we do not control the weather, for example. The human effort is more one of trying to understand the complex natural systems, to make use of what happens and what is produced naturally, and to channel it to our purposes. By contrast, in the production of synthetic fibres we feel we have complete control over the whole process because the chemical and physical processes used are inherently less complex and therefore more possible for us to understand conceptually than biological processes. We can accurately specify the conditions of temperature, pressure and reactants under which the processes occur and can provide these within simple, closed systems which can be closely monitored and controlled. These systems and processes allow us to produce substances that are unnatural in the sense that without human action they would not exist at all on earth.

In agriculture, organic farming techniques are considered more natural than modern chemical farming technology which uses pesticides and inorganic fertilisers. Both aim to provide suitable conditions for natural biological processes to occur – for crop plants and livestock to grow. But organic farming relies on natural processes, *i.e.* on ecological relationships to control pests and on soil microbiology to provide plant nutrients (through the breakdown of organic matter), whereas chemical farming uses synthetic chemicals as substitutes for specific, discrete processes in the ecosystem. As the application of these chemicals is fully under the control of the farmer, chemical farming seems to give the farmer more control than organic farming does. This has enabled the farm to become like a factory, with a one-way flow of inputs of chemicals and energy at one end and outputs of a limited number of "products" at the other. Of course there are other outputs apart from the desired wheat grain, beans, meat or fibre, but these are classified as "wastes." In this system, monoculture on a scale not conceivable before is made possible. In contrast, traditional and organic agriculture normally has to involve a variety of crops and processes. The farm has to be run as an integrated cyclical system where "wastes" from some processes form inputs into others.

The above discussion suggests several strands to the natural/unnatural distinctions made with regard to human technologies:

- natural methods typically depend on biological processes and interactions which occur in living nature, whereas the paradigm cases of unnatural technologies are based on physical/chemical processes;

- natural methods have typically been developed through experiential understanding of those processes over many years of practice of the method, though this understanding may be enhanced by insights from scientific research, whereas the development of unnatural technologies has been based upon scientific theories about physical/chemical processes (or biological processes seen as reducible to physical/chemical ones);
- because chemical/physical processes are simpler and therefore easier to understand conceptually (*i.e.* scientific theories can give a more complete description of them) they are easier to control and manipulate: when we employ unnatural methods we feel that we have more control over the outcome than when we use natural methods;
- while natural methods involve humans understanding natural processes and then adapting their behaviour or channelling the natural processes to meet human ends, unnatural methods aim to give human behaviour a freer rein: nature is to be altered to suit human behaviour, institutions and practices, so the latter are freed from the constraints imposed by nature;
- this freedom has been used to create new kinds of things that have not before existed in living nature: things that are novel.

I would like to stress that all of these strands are matters of degree, of more or less, not either/or: naturalness and unnaturalness are relative, not absolute. I also recognise that they are not rigorous criteria, more pointers to what may be meant by natural/unnatural when it comes to technology. Although the strands are interrelated, the position of a particular technology on the unnatural/natural spectrum may depend on which particular strand you consider. It may not therefore be possible always to rank technologies relative to each other on a single scale of 'naturalness.'

Is genetic engineering an unnatural technology?

Using these distinctions, can genetic engineering be called unnatural? Here I take genetic engineering to be the practice which seeks to produce altered organisms through direct intervention at the level of the DNA of the organism, by means of laboratory methods such as recombinant DNA technology. It certainly uses living biological systems and is not an attempt to replace such systems with physical/chemical processes. However, it is based on the idea that biological processes are essentially reducible to physical/chemical ones, and therefore in principle amenable to being controlled by us to a similar degree. So the characteristics, properties and capacities of each living organism are regarded as 'encoded' by the organism's DNA sequence: being able to change that DNA is the key to having control over what a living organism is.

The rationale behind genetic engineering is that nature should be altered to suit human practices and institutions. The institutional context within which the technology is being developed (market economies dominated by large corporations) has defined the practices that organisms are to be genetically engineered for. Thus amongst the first genetically modified crops have been soya beans resistant to specific herbicides, and tomatoes that do not rot and thus have a longer shelf life. There is also interest in engineering peas to make all the pods on a plant ready at the same time. These are "improvements" to these plants only in the context of certain agricultural and food industry practices: the use of herbicides to keep down weeds, long distance transport of food from field to shop, and mechanised harvesting.

This rationale is, of course, shared by traditional plant and animal breeding practices, which thus also have an element of unnaturalness about them. What makes genetic engineering different is that it does not simply make use of processes which occur in nature – it is not natural selection consciously put to human ends and thus rendered artificial or methodical, as Darwin termed it (Darwin 1905). Pure DNA (*i.e.* DNA stripped of the proteins and other molecules normally associated with it) does not exist outside the laboratory. Its manipulation is not a variation of a process which occurs in natural systems; neither is the micro-injection of DNA into fertilised egg cells. These new methods enable us to create things that have not existed before: transgenic organisms, containing one or more genes from an unrelated species. Despite the protestations that species are fluid, changeable entities, that there are no 'natural species boundaries' for genetic engineering to cross (see for example Straughan 1999), no one denies that genetic engineering techniques enable movements of genes between species that could not have occurred before.

The methods of genetic engineering, it is claimed, overcome the limitations of traditional breeding practices. They are intended to greatly enhance the human abilities to control and change nature to suit human practices and institutions. In this respect they are much more unnatural than traditional breeding practices. Unlike traditional breeding genetic engineering is also unnatural in that it enables the creation of transgenic organisms: a step up from the sort of novelty that is possible with traditional breeding.

What is wrong with unnatural technologies

The term unnatural has overtones of moral disapproval. Similarly, the word exploitation is often thought to imply moral wrongness. However, it has been argued (Wood 1995) that exploitation is not a moral term, but a descriptive one. To call something exploitation is not in itself to say that it is wrong, but the nature of exploitation, combined with particular moral beliefs, means that exploitation is, in many instances, morally wrong. This separation of the descriptive from the moral overcomes the charge of an is/ought confusion. The preceding sections have given some content to the term unnatural when applied to human technologies. This section will examine that content from an ethical standpoint to explore whether and how, given certain moral beliefs, moral wrongness follows from the unnaturalness of a technology, looking in particular at the example of genetic engineering. There are three aspects of unnatural technologies that I will consider: the attitude to nature that unnatural technologies embody; the novelty of the processes they involve and of the things that they make it possible for humans to produce, and their consequences for human social and economic structures.

Attitude to nature

Implicit in the move that unnatural technologies make from biological to chemical/physical processes, to enable greater control in the attempt to modify nature to fit in with human purposes, is the idea that nature is a constraint and limit on human action. The view exemplified by Francis Bacon's phrase 'conquer and subdue,' was that of nature as an antagonist, to be overcome and brought under our control (in Bacon's *Wisdom of the Ancients* "Erichthonius," Myth 20 - Robertson 1905:843)[1]. Also in this vein is the awe, verging on terror, at the vast, reckless power of nature that suffuses J.S. Mill's essay (Mill 1904). In contrast, a contemporary, post-modern view is that nature is simply a social construct – all 'natural things' are in fact merely constructed as such by human practices, and therefore there is no fundamental difference between the artefactual and the natural (see for example, Vogel 1996). On this view one cannot make the distinction I am proposing between 'natural' and 'unnatural' technologies, so there can be no moral difference between them.

In opposition to both the old idea of nature as an awe-inspiring antagonist and the post modern denial of a nature independent of human practices, the proponents of natural technologies, particularly of organic farming (the 'natural technology' that has been most written about) regard nature and nature's processes to be beneficial overall – though particular natural things or events may, of course, be harmful (see, for example Verhoog *et al* 2003, on the attitudes of organic

[1]Though it should be noted that Bacon argued against forcing nature to our will in order to 'conquer and subdue it;' this approach 'rarely attains the particular end it aims at' and Bacon recommends instead wooing nature with 'due observation and attention' (in Robertson, 1905:843).

farmers). Natural processes and living organisms have their own autonomy, an 'otherness' that is always, to some extent opaque to human understanding: nature 'lives and grows by itself' (Verhoog *et al* 2003, 39). Organic farmers regard nature as an autonomous partner, with whom they are co-operating, and who should be respected. This respect, like the respect that one owes a friend, is a moral duty. It also, though, has its pragmatic side (if one divorces moral reasons from pragmatic ones): the early organic movement argued that only organic methods (specifically the use of animal manures to replenish the humus content of the soil) would keep the soil healthy, and only a healthy soil would produce healthy crops, animals and people (see Conford 2001).

The organic movement thus argues that organic farming results in material improvements to human life, compared with conventional agriculture. One can also argue that the relationship to nature it embodies is of importance to human well-being in a constitutive, not merely an instrumental sense. In such constitutive relationships, what one has a relationship with (the other), because it is different from and independent of the self, offers resistance to and puts limits on the activities of the self. Not to respect those limits, but instead to seek simply to control and dominate the other, is to attempt to make the other into merely an extension of the self: something that exists simply to meet ends defined by the self. This denies the possibility of a relationship with the other, a relationship that could have enriched the self. The self is thus diminished if it denies otherness by not respecting the limits that the independence of others places on it (Plumwood 1993). Recognition of and respect for the otherness of natural processes is thus essential if we are to have a relationship with nature that can become part of who we are.

It is through engaging with living organisms and natural processes in technology that we encounter this otherness. Sometimes it is as a resistance to our preconceived plan, that then has to be adapted and modified to achieve our end: we must eat, but we can change our ideas of what we should eat according to what the environment we are in affords; the farmer or gardener can either do battle with pests (slugs in my case) or grow crops that are not so vulnerable to their attack. Otherness can also be encountered as an unexpected gift: the natural bounty that we have not worked for, that is simply there for the taking. Both would be lost if we truly mastered the otherness of nature and brought it under our full control.

Using more unnatural technologies means reducing the engagement of individuals and society as a whole with nature: we lose the encounter with the otherness of nature, diminishing our relationship with it and thus with ourselves. When we go from using wood to using plastic, or from wool to acrylic, we as a society are no longer dependent upon, nor need to have interaction with, the forests where the trees grow or the sheep who provide the wool. Instead of forests and fields we need oil refineries and chemical factories. Ways of life that did involve engagement with nature are destroyed. Mark Sagoff points out that making us less economically dependent on the natural environment is indeed the intention of biotechnology. Genetic engineering would enable a huge range of products to be produced by cell culture techniques, dramatically increasing the degree to which industrial (*i.e.* unnatural) products replace those of agriculture, with the latter confined to the growing of biomass (Sagoff 1988).

This argument, that part of what is wrong about unnatural technologies is the attitude to nature that they embody – that they do not respect and value nature and natural processes, but simply seek to have controlled, predictable outcomes – is, like other arguments I am making, a relative one. Human life necessarily involves trying to have some control over our environment and the products of our labour. However, there is a vast difference between the primitive 'gardening' of hunter/gathers, that encouraged the growth of desirable plants and discouraged others, and the attempt to genetically engineer a plant so that it has a particular defined set of characteristics that we want it to have. Some forms of control respect the otherness of what we are engaging with: they seek to channel natural processes so they produce outcomes we desire, but are receptive to the qualities and properties of natural processes, materials or organisms and allow these to influence and constrain our desires. In contrast, other forms of control are not receptive in this way and seek rather simply to impose the human will on nature.

Novelty

To say that something is novel is to say that it is a new kind of thing, not simply that it is a recent incident of a general kind. Days and babies can be new but not novel (though genetic engineering raises the possibility of novel babies). This aspect of the unnatural gives a clear temporal dimension to the idea of nature. Nature is the 'pre-given' – even if it is a legacy of an earlier culture rather than a 'nature' free from human intervention (Soper 1995, 187). In a related way the natural is the ordinary, the normal (Mill 1904, 30). Here nature is clearly given a relative, rather than an absolute meaning: the degree of unnaturalness depends on the newness of the novel (*i.e.* new kind of) thing and on the extent to which it is different in kind from what has gone before.

If something is novel then it is something that we have no experience of. We therefore cannot use our past experience as a guide to what will happen and what we should do. In the case of the processes and products of unnatural technologies, what we use instead of such experience when we think about what the impacts of these technologies might be is the scientific knowledge –

conceptual understandings or theories – on which these technologies are based. In doing this we are assuming firstly that our theories give adequate descriptions and understandings of the relevant phenomena, and secondly that we know what the relevant phenomena are: that we know which areas of knowledge are pertinent to the question of what the effects of the particular novel process or product will be. These assumptions are highly questionable. The experience of environmental concerns over the past century, for example, is that many of what have turned out to be the most serious impacts of new technologies were not, and probably could not have been predicted when those technologies were introduced. The classic case is the effect of CFCs (chloroflurocarbons) on the ozone layer. When these chemicals were first synthesised in 1928 no one would have considered atmospheric chemistry to be relevant to assessing the impact of a proposed refrigerant. CFCs were simply welcomed because they did not have the problems of flammability or toxicity associated with previous refrigerants (Colborn *et al* 1996, 243-245). We cannot assume that theoretical knowledge alone is capable of giving us an adequate understanding of the world. There will always be areas of 'irreducible ignorance,' which put limits on the possibilities of scientific knowledge: even with unlimited research, in some cases, we will not be able to predict the consequences of taking a particular course of action, in the sense of knowing all the possible outcomes and their probabilities (Faber, Manstetten and Proops 1992).

This concern about unnatural technologies is related to the former issue of the attitude to nature embodied by unnatural technologies. Nature should be recognised as an 'other' partly because it is to some extent opaque to human understanding. This inability of the human mind to fully understand nature was part of the Greek concept of *techne*. *Techne* involves being able to reason correctly on the basis of knowledge about the form of what is to be made and the matter it is to be made out of. However, Aristotle considered that it was only possible to know matter "up to a point" (*Physics* 2.2.194a23). In itself matter is unknowable. It is also not simply formless stuff, which any form can be imposed on, but it 'desires' or 'reaches out' for particular forms (*Physics* 1.9.192a18). The artisan must therefore be attentive to the particular matter being worked on, and allow the matter to guide the form of the artefact. Only then will the artefact approach the perfect union of form and matter that is characteristic of natural objects (Mitcham 1994, 118-123).

Genetic engineering's reliance on a particular conception of the role of DNA in the growth, development and final form of an organism[2] makes the technology particularly open to the charge that it is tampering with things we do not understand. This conception, in which organisms are regarded as collections of separate, distinct functions or properties, each determined by one or more genes, is a disputed one. Brian Goodwin, for example, proposes instead a conception of organisms as dynamic wholes, in which genes, through their specification of the particular form of proteins, influence the outcome of the process of growth: the proteins, and thus the genes which specify them, do not on their own determine particular characteristics of the organism (see Goodwin 1994). From this standpoint the results of transfers of genes from one organism to another are inherently unpredictable and Goodwin, with other scientists at a meeting in Penang, Malaysia in July 1994, called for a moratorium on the release of genetically modified organisms into the environment.

Unnaturalness is thus a way of talking about radical uncertainty, or ignorance about the effects of a new technology. It is not the only source of uncertainty in the world: the consequences of human actions are generally unpredictable, but we nonetheless have confidence in the future if we believe we will be able to cope with the range of things that are likely to happen. However, the novelty of unnatural technologies means that their effects may well be outside of the range of previous experience and perhaps the ability to cope of natural ecosystems as well as of human societies. These considerations urge a precautionary approach: one that recognises our ignorance and does not pursue an unnatural technology unless there are very good positive reasons to do so. Not to recognise ignorance in this context is arrogant; to proceed in spite of such ignorance without very good reason is reckless and irresponsible.

Social consequences

Any impact of a technology is a function of both the intrinsic nature of the technology and the context within which the technology is used. This is true for social as well as for environmental impacts. Thus, although the context of social institutions and relationships, such as property relations and the distribution of wealth, are important in determining the impact of a technology, the nature of a

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[2]The conception of the role of DNA implicit in genetic engineering is that particular sequences of DNA (*i.e.* genes) determine particular characteristics of an organism through the specification of proteins, with a simple, one-to-one (in what is considered the normal case) relationship between the characteristic and the gene. Only within this framework can it make sense to attempt to create an organism with a desired new characteristic by introducing the 'gene' – *i.e.* the DNA sequence thought to 'encode' for that characteristic – into the genetic material of the organism.

technology may also be such that the technology will have a tendency to change human social and economic relationships in a particular way.

What happens when a more unnatural technology replaces a more natural one is that there is a reduction in the reliance on natural processes and an increase in reliance on products and processes that are humanly instituted and controlled. The latter products and processes are on the whole ones developed, informed and mediated by expert scientific knowledge of the kind which requires the support of government or large corporations for its growth and development. This, I think, means that, contrary to the idea that unnatural technologies increase human autonomy by transcending natural limits, it is generally the case, on the level of individual people, that the more unnatural the technology, the greater the reduction in the concrete experience of autonomy. While the autonomy of human society with regard to nature is increased, that of human individuals with regard to controlling human institutions is decreased.[3] As C.S Lewis said in 1947, "What we call man's power over nature turns out to be a power exercised by some men over other men with nature as its instrument." (Lewis 1947)

In the debate about genetically modified crops this aspect has been clearly recognised. Many are opposed to the technology because of the effects it would have on the power structures within agriculture, taking power away from individual farmers and giving it to the large biotechnology companies. However, I do think this is a general feature of unnatural technologies. It arises because natural technologies are generally based on more widely dispersed resources and knowledge and are more amenable to being carried out on a small scale. They are therefore inherently more likely to create a more equal distribution of wealth and power than unnatural technologies. This is not to say, of course, that a society using more natural technologies will necessarily have a more equal distribution of wealth than one using unnatural ones. Access to land and therefore natural resources can be artificially restricted by forms of property ownership which give a minority of people control over most of the land. Similarly, a society using unnatural technologies can institute employment laws and welfare benefits to give a more equal distribution of wealth. But in the former case social and institutional forces need to be mobilised to maintain an

[3]Thus, in *The Dialectics of Enlightenment*, Horkheimer and Adorno argue that the Enlightenment's attempts to dominate and thus liberate humans from nature paradoxically results in the domination of the human subject by "second nature" – human institutions and technology (discussed in Vogel, 1996). But this is only a paradox, *i.e.* a return of what has been suppressed, if the controlling human institutions are mistakenly regarded as "natural" and the human responsibility for them denied.

unequal distribution,[4] whereas in the latter they are needed to create a more equal one.

Conclusions

In conclusion, moral wrongness follows from the unnaturalness of a technology in virtue of: firstly, the attitude to nature that they embody, that seeks control over rather than respectful engagement with nature; secondly, the recklessness of using novel processes and products, the consequences of which we are inherently ignorant, or the arrogance of not being aware of this ignorance, and thirdly, the concentration of wealth and power in human societies and the reduction in the autonomy of human individuals brought about when a more unnatural technology replaces a more natural one. To the extent that a particular technology embodies these attitudes, is novel, and has these consequences for the relationship between human individuals and their natural environment, and thus human social and economic relations, it can be considered as ethically suspect.

It should be noted that none of the above involve regarding nature as a standard to be conformed to or a model to be followed. If there is an appeal to an independent nature it is to a particular conception of human nature, one that considers forms of human life that respect the otherness of nature, that seek to understand and adapt to the natural environment and that acknowledge the limits of theoretical knowledge, to be objectively better than ways of life that seek to control and dominate and that are arrogant about the extent of human powers and knowledge. Technology, which defines and embodies our concrete, practical relationship with nature plays an active, non-neutral role in determining our way of life, and is therefore is a matter of ethical concern. The "unnaturalness" of a technology is, I have argued, a set of characteristics which appears, on the whole, to render that technology ethically dubious. However, this does not mean that other criteria are not also relevant to the moral evaluation of technologies. None of the arguments advanced here are intended to imply that if something can be said to be 'natural,' it follows that it is necessarily good.

Postscript on feeding the world

In the section above on novelty I argued that our ignorance with respect to unnatural technologies means that we should not proceed with them unless there are good, overriding reasons for doing so. In debates about genetic engineering, what is often put forward as such a good reason is the need to feed the growing

[4] For example, those in power often need to use force to prevent occupations of land by the landless.

world population: genetic engineering is needed to increase the productivity of agricultural systems. I find such arguments extremely unconvincing.

Firstly, all the evidence suggests that the cause of hunger is not lack of food, but social inequalities – there is plenty of food, it is just that some people do not have access to it (see for example Kimbrell 2002). These social inequalities, I have argued, are increased, not decreased by unnatural technologies: genetic engineering is thus likely to increase, not decrease hunger. If lack of food were a problem, the easiest way to remedy it would be for livestock farming to become less intensive, using less imported feed and more extensive grazing on land unsuitable for crops (see McLaren, Bullock and Yousuf 1998 on the huge amount of land, often in countries where hunger is present, used to grow soya and other crops for UK livestock).

Secondly, many studies have shown that food production by small scale farming can be dramatically increased with organic methods and other 'agroecological innovations' (see Parrott and Marsden 2002, and Uphoff 2002). Such natural methods do not diminish the independence of small scale farmers because they do not rely on expensive internal inputs such as fertilisers and pesticides. They also increase food supply at the point where it is vulnerable to scarcity, on local markets in countries of the South.

Thirdly, nature, not the work of humans, is the source of productivity and abundance. Therefore understanding natural processes and working with rather than against them, using what nature provides rather than manufacturing something else, maintaining rather than destroying the productivity of natural systems, are all, in the long run, likely to provide more benefits for less effort.

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Canada's Three Mute Technological Critics

James Gerrie
jgerrie@uoguelph.ca
University of Guelph
Wilfrid Laurier University

In Martin Heidegger's 1953 lecture "The Question Concerning Technology" (1977), and Herbert Marcuse's 1941 article "Some Social Implications of Modern Technology" (1998) one finds expressions of philosophical critiques of technology that emphasize the intimate relationship between technology and everyday human practice. Around the same time that Heidegger and Marcuse were forming their groundbreaking perspectives on modern technological civilization, three pioneering Canadian technology theorists, Harold Innis, Marshall McLuhan and George Grant were also developing critical practice-based understandings of technology. In Innis' concern about "the mechanization of knowledge" expressed in his 1948 address to the Conference of Commonwealth Universities at Oxford, McLuhan's concept of the medium as message first presented in 1951 in *The Mechanical Bride*, and Grant's discussion of the effects of technology on "all the forms of life" in his 1955 address to the Annual Couchiching Conference, one finds practice-based understandings of technology, which emphasize the danger that technology poses to our civilization. Over the course of their careers each of these three thinkers also argued that our ordinary involvement in technological practice can create a dependence on a technological approach and that meeting the ethical challenges of technology must involve an appropriate awareness of this kind of dependence.

Arthur Kroker's seminal work on these three figures, however, emphasizes the dissimilarities of their positions on the ethical implications of technology (Kroker 1984, 18). According to Kroker, McLuhan is an optimistic herald of the new information age, Grant is a dark prophet of technological society, and Innis is a practical-minded intermediary between these two visions of our technological future. John Goyder, on the other hand, argues that there is a certain similarity between the perspectives of Grant and McLuhan, but that this shared perspective results not in a critical attitude towards technology but "a state of fascinated ambivalence" (Goyder 1997, 239). The following investigation, in contrast, argues that a greater fundamental unity can be found in the varied responses to the ethical challenge of technology of Innis, McLuhan and Grant and that their general ethical approaches to technology are significantly more critical of technological development than either Kroker or Goyder acknowledge.

Innis, McLuhan and Grant are generally acknowledged as constituting "the foremost group of 'technological critics' in Canada" (Goyder 1997, 239). Unlike some intellectuals, they did not avoid involvement in public life. According to Daniel Drache,

> More than any other Canadian scholar in recent times, Innis's prodigious writings on political economy shaped the views of his contemporaries, from Donald Creighton, one of Canada's most eminent historians, to Marshall McLuhan, a world figure in communications theory. As a leading university administrator, Innis was a moving force in the founding of the Social Sciences Research Council of Canada and a key figure in public life while dean of graduate studies at the University of Toronto. Throughout much of his adult life, Harold Adams Innis was Canada's pre-eminent thinker and theoretician. He had the stature of a Galbraith in public policy; governments beat a path to his door for advice and counsel. (Drache 1995, xvii)

McLuhan played the role of public intellectual and "was a worldwide celebrity by the late 1960s, an overnight sensation created by the same forces that his work described" (Rawlinson and Granatstein 1997, 231). Grant wrote books for wide public audiences in Canada, such as *Lament for a Nation* (1965), which was highly praised both by nationalist conservatives and members of Canada's new left movement in the late sixties. As a result, as Rawlinson and Granatstein note in their survey of Canada's most prominent twentieth century intellectuals, "Grant's influence on the public and the politicians was immense. Even today in a much more integrated North America, Grant's lament continues to rally the nationalist tories, the left-Liberals, and the social democrats" (Rawlinson and Granatstein 1997, 188). None of these three thinkers was a shrinking violet when it came to politics and public involvement, yet in all of their extensive writings on technology there is a strange silence about the practical matter of how to best go about making practical judgements about technologies and technological issues.

Carl Berger suggests that an impractical or even determinist approach to social and political issues was an integral part of Innis' outlook throughout his career. He notes that "for reformers, Innis appeared to dwell excessively on what men could not do. . . . He had an anti-reformist bias. . . He often seemed more impressed—one might almost say overwhelmed—with the intractability of the forces at work than with the prospects for precise solutions" (Berger 1976, 103). And although Innis served on several commissions of the national government of Canada, "he tended to be scornful of those academics who were eager to serve governments at every opportunity. Scholars should teach and research, not be policy makers" (Berger 1976, 96). Philip Marchand similarly notes that one of the persistent forms of criticism leveled at McLuhan was "that he was complacent about the phenomena he described and indifferent to matters of social justice" (Marchand 1990, 191). Even a sympathetic colleague, Abraham Rotstein, could make observations like the following: "But the march of modernity in seven league boots to some imminent global unity was equally mesmerizing [to McLuhan].... But he offers no systematic social or philosophical critique beyond a present critical vigilance and a future benign anticipation" (Rotstein 1985). McLuhan is popularly held to have been one of the twentieth century's most provocative thinkers about modern communications technologies. And yet no practical program for dealing with the negative effects of these technologies is generally recognized as having emerged from his work. As Northrop Frye notes, "he has come down as a kind of half-thinker who never worked out the other part of what he was really talking about" (Frye 1992, 161). It has also been noted of Grant that while he was a severe critic of technological civilization, he was largely silent about practical responses to specific issues. Ian Box argues that "specifically, he offers little in the way of systematic criticism of technological civilization, and no constructive alternatives to our present disorder are put forward for consideration" (Box 1982, 504). William Christian, on the other hand, argues that one can at least find indications of "an implicit and positive teaching in his writings" (Christian 1983, 350). Others have noted in Grant's work a pervasive attitude of despair in the face of the problems of modern life, as can be seen in titles of articles such as John Muggeridge's "George Grant's Anguished Conservatism," William Christian's "George Grant and the Terrifying Darkness," Edwin and David Heaven's "Some Influences of Simone Weil on George Grant's Silence" and Dennis Lee's "Grant's Impasse."

Why should three of Canada's most notable twentieth century technological critics, who were generally not reticent about publicly expressing their views, seem so reticent when it came to making practical suggestions for how we should go about making choices concerning a subject which came to dominate their academic work? In his later work Innis shifted his interest from economic history to the dynamic of technological change. In particular in these later works, as Drache notes, "the point he repeatedly emphasized was that everyone had to be conscious of the contradictory potential of each new technology" (Drache 1995, li). Grant came to see technology in Heideggerian terms as the "endeavour which summons forth everything (both human and non-human) to give its reasons, and through the summoning forth of those reasons turns the world into potential raw material, at the disposal of our 'creative' wills" (Grant 1974, 88). Or as he puts it elsewhere, technology is the merging of two fundamental types of human activity, "knowing and making," in which "both activities are changed by their co-penetration" (Grant 1986, 13). For him, technology is more a process than product, and this process is most fundamentally concerned with "the domination of man over nature through knowledge and its application" (Grant 1986, 4). For McLuhan dependency involves a "subliminal and docile acceptance" of technology (McLuhan 1977, 103). This attitude is a result of a distinctive form of unconsciousness that he thinks attends most of our technological activities. The problem is not one of false consciousness or false needs, but a lack of consciousness at all of the changes that technology rings in oneself and society. The result is that "a man is not free if he cannot see where he is going" (McLuhan 1977, 103).

While each of these thinkers was known for having severe misgivings about the course that technological civilization was taking, none of them undertook to describe anything in the way of a systematic approach to responding to the kinds of ethical challenges that technology can present. Their silence in this regard is a mystery worth considering. It could be suggested that they were simply detached ivory-tower academics. However, their willingness to participate in public debate seems to belie such a claim. My counter hypothesis is that for them, the challenge of technology was located in the very nature of technology itself, as a distinctive form of human activity, and that this perspective explains their refusal to advocate a systematic response to the challenges of technological civilization. I will argue against the claim that these three prominent Canadian intellectuals generally advocated a neutral or ambivalent position on the issue of technology.

At the core of the silence of Innis, McLuhan and Grant is a shared understanding of the technological phenomenon as encompassing all formalized and systematic problem-solving practice. Technology is any kind of formalized practice we can habitually engage in, whether in the form of a technique or technique and artifact, to respond to commonly encountered difficulties. Each sees proper awareness of this aspect of technological practice as being essential to our proper understanding of technology. They share the position of rejecting a search for a systematic ethical or political approach because such a search can too easily turn into the very kind of habitual technological response they wished to put into question. Each dealt with this realization in a different way. Innis began to refuse work on public commissions or to serve governments as a policy consultant (Creighton 1957, 110-111). After the publication of *The Mechanical Bride*, McLuhan publicly renounced what he called "the error of critical moralism" (Fitzgerald 2001, 78). Grant refused to act as apologist for the political programs of either the left or the right (Reimer 1978, 49-60).

We can see the first glimmerings of Innis' understanding of the centrality of habit for technological practice in his address, "A Critical Review," presented to the Conference of Commonwealth Universities at Oxford University in 1948 and later published as *The Bias of Communication*. The following is his introduction to that address:

> I propose to adhere rather closely to the terms of the subject of this discussion, namely, "a critical review, from the points of view of an historian, a philosopher and a sociologist, of the structural and moral changes produced in modern society by scientific and technological advance." I ask you to try to understand what that means. In the first place, the phrasing of the subject reflects the limitations of Western civilization. An interest in economics implies neglect of the work of professional historians, philosophers, and sociologists. Knowledge has been divided to the extent that it is apparently hopeless to expect a common point of view. In following the directions of those responsible for the wording of the title, I propose to ask why Western civilization has reached the point that a conference largely composed of university administrators should unconsciously assume division in points of view in the field of learning and why this conference, representing the universities of the British Commonwealth, should have been so far concerned with political representation as to forget the problem of unity in Western civilization, or, to put it in a general way, why all of us here together seem to be what is wrong with Western civilization (Innis 1951, 190-191).

For Innis, the assumption of conference organizers that an academic conference on the future of the university should be structured along the lines of academic specialization was a manifestation of the kind of technological mindset he wished to combat. William Westfall notes that for Innis the university in the post-war period had "become synonymous with specialization and departmentalization" and that "with a professionalised university we have succumbed to the very pressures that Innis had worked so hard to oppose" (Westfall 1981, 45). John Watson sees Innis as a tragic figure because "the sad truth is that the continuing struggle he waged against specialization in the social sciences and for an authentically indigenous school of scholarship has largely been lost since his death" (Watson 1977, 45). The influence that ingrained beliefs, or bias as Innis called such beliefs, was to become the essential focus of Innis' understanding of technology.

The emphasis on the aspect of unconscious habit or bias in technology is common to all three of these scholars. Grant puts this point bluntly when he states "We are technique" (Grant 1969a, 137). Technology is for him a process in which all people participate so intensely through the actions of their "hourly existing" that it is almost impossible to conceive of them bringing this process under any kind of sustained ethical scrutiny. He comments that "every moment our existence is so surrounded by the benefits of technology that to try to understand the limits to its conquest, and also its relation to human excellence, may seem the work of a neurotic seeking to escape from life into dream" (Grant 1959, vi). According to Grant, the fact that technological activity has come to dominate the lives of most modern individuals presents them with a unique dilemma. Since this fundamental way of acting has become so second nature, when it comes to addressing issues that might suggest possible limits to this kind of activity, their tendency is to engage in this kind of activity rather than to consider its limitation. Or, as he puts this point, "We are at the mercy of the technological machine we have built, and every time anything difficult happens, we add to that machine" (Grant 1969c, 3).

McLuhan also believed that the intimate engagement of modern individuals with their technologies prevents a proper awareness of the ethical implications of these technologies. In his book *Understanding Media*, he describes at length how the intensity of the process of technological change can "numb" one's sensitivity to this process (McLuhan 1964, 41). The origin of this numbness is in the nature of all technologies as "extensions of some human faculty—psychic or physical" (McLuhan 1967, 26). In the same way that most people are normally unaware of thought when they are thinking, or of their hands when they are grasping, or of their mouths when they are speaking, they are normally unaware of their technologies in their regular use. In most natural and unmediated human activities one's focus is on the task itself and one's goals and not the means (the various parts of our body or mind) being used to achieve these goals. This means that it is precisely the "tools" with which we are most familiar that we will be most blind too, in the same way that a medium of communication, such as a television, fades into the background when we are focused on the message it is conveying.

For McLuhan there seem to be two primary supports of this normal lack of awareness. The first is the result of the simple intimacy that is an integral characteristic of technology as an extension of oneself. His suggestion is that in our technological actions, just like in our unmediated actions, we are normally unconscious of the various parts of our functioning body and mind. He puts this point as follows: "The principle of numbness comes into play with electric technology, as with any other. We have to numb our central nervous system when it is extended and exposed, or we will die" (McLuhan 1977, 106).

As McLuhan suggests on many occasions, it is only when technologies have passed from normal use that they typically become objects of conscious appreciation, such as when they become objects in museums. It is for this reason that McLuhan compares most attempts at understanding the ethical impact of technologies to an attempt at driving a car by way of its rear-view-mirror (McLuhan 1967, 100).

However, there is another important source of a general lack of consciousness of our technologies and their effects. According to McLuhan it is also the habitual nature of most technological activities that contributes to the tendency to overlook these activities. As he puts this point, "It is this continuous embrace of our own technology in daily use that puts us in the Narcissus role of subliminal awareness and numbness in relation to these images of ourselves. By continuously embracing technologies, we relate to them as servomechanisms" (McLuhan 1977, 103). All technologies involve us in routine forms of practice. From the grain pounding mill of rural villages in developing nations, to the procedures of airways management of large airline hub cities in the developed world, routine procedure is the name of the game when it comes to technology. And this very routine-ness can, according to McLuhan, contribute to a lack of awareness of the implications of such practice.

Innis, Mcluhan and Grant are each concerned with understanding unconscious social processes. As Leslie Pal notes, "The subject matter which Innis retained for social science was habit or bias. [In choosing this subject,] Innis was suggesting that while some human activity is consciously and spontaneously directed much of it appears to be the result of unreflective and ingrained behaviour" (Pal 1977, 33). Grant's fundamental philosophical approach to technology, as Philip Hanson describes it, was to become "a spectator, waiting and listening to the speeches, rituals, and strivings of a society dominated by technique" (Hanson 1978, 308). McLuhan writes that "man is not only a robot in his private reflexes but in his civilized behaviour and in all his responses to the extensions of his body, which we call technology" (McLuhan 1968, 19). They each look past the obvious and sometimes grandiose failures of technology to the nature of technological action itself.

They each saw a need to develop an approach to technology in which the character of technological action as habit is consciously examined. However, each also suggests that the deep-rootedness of a technological approach can even lead us to habitually seek technological solutions to this problem. Innis presents this dilemma in the following fragmentary note taken from his *Idea File* (Innis died at age 58 with a substantial part of his technology-focused work left unedited):

> Mankind is continually being caught in his own traps--[once specialist] language and systems [are] developed [they become] difficult to break down . . . . [The ancient] Greeks had the advantage of debating without control but the development of a written tradition [strengthened the power of specialist language and systems. An emphasis on] control [by way] of systems followed--[the legal code] used by [the] Romans [being one example]. [Early written] communication [was] limited to a small number--[resulting in a] hierarchy of philosophy--[Humankind's] egoism makes it more difficult to secure relief [from the tyranny of specialist language and systems because]--mankind's belief in his own contrivances [prevents him from questioning his commitment to these contrivances] (Innis 1980, 6.50).

As Innis points out, our dependency on technologies and technological problem-solving practice is further augmented by the fact that every technology is a source of power.

For Innis, any new form of technological capability creates a definable group who will benefit from the application of that capability. These "elites," as Innis calls them, have an interest in maintaining a situation conducive to the development and continued use of the technologies that benefit them. The term "elite," as used by Innis, is not meant to carry the notion that such groups will necessarily be privileged minorities. His use of this term is meant, instead, to suggest, in a manner similar to the work of Foucault, that any new technology always results in the creation of a definable group that gains an advantage from the use of a technology and also a group that does not. Technologies must, according to Innis, inevitably set up distinct bodies of individuals, ranging from immensely large to immensely small, which can come into political conflict. Whole nations/linguistic groups, for example, are said by him to have emerged because of their commitment to certain technological conventions, such as when he states that "the Dutch language had an existence separate from Germany because it was fixed early in writing" (Innis 1951, 125).

Innis' later work focused on what he called "monopolies of knowledge," which he describes as "channels of thought" and practice that emerge in civilizations through the adoption of new technologies (Innis 1951, 4). Arthur Kroker suggests that "long before the French philosopher, Michel Foucault, said that *power* is the locus of the modern century, Innis in his studies of neotechnical capitalism had already revealed exactly *how* the power system works: by investing the body through capillaries of diet, lifestyle, and housing" (Kroker 1984, 120). Innis uses the term "monopoly or oligopoly of knowledge" to describe any situation of a specific group of people benefiting from a technology (Innis 1951, 64). New technologies unleash changes in societies because they disrupt existing knowledge monopolies. As new challenges arise which cannot be addressed by existing elites, new technologies and new groups arise to address these new challenges. These new groups, however, inevitably support the creation of new knowledge monopolies, which help give rise to new forms of rigidity and disequilibrium in society in the face of changing circumstances. These strains in the social framework create the need for new technologies. McLuhan describes a similar process when he suggests that:

> It is the accumulation of group pressures and irritations that prompt invention and innovation as counter-irritants. . . . physiologically, man in the normal use of technology (or his variously extended body) is perpetually modified by it and in turn finds ever new ways of modifying his technology. (McLuhan 1964, 46)

Watson argues that Innis' later work focuses almost exclusively on

> an examination of how a different dialectic [than that of Marx], the

> dialectic of power and knowledge, was played out in human history using communications systems as a focus for analysis of this process. . . . The effect which Innis predicted was a tendency away from critical thinking and towards following orders on a mass scale (Watson 1977, 58).

One reason that critical thinking can be threatened by the ordinary process of technological practice, according to Innis, is because seeking to manage this process as a whole can itself become a source of power. He notes that "constant change in capitalist society--compels administration to keep constantly alert to protect themselves against and to take advantage of any particular change" (Innis 1980, 5.20). Professional innovators, facilitators of innovation can become engaged in the project of "development" and in this way be considered to constitute a technological elite with an interest in encouraging and directing technological change in general. Such a broad conception of technology's influence obviously puts the ability to think freely about technology at an extreme premium, on Innis' analysis.

Innis felt that the university was the only place from which to expect any understanding of the influence of bias to emerge. He believed that it was the only place dedicated in principle to producing authentic social criticism of the application of human knowledge and creativity. As he puts it: "[The] Place of learned class [and] universities [is] to prevent domination of various groups -- church, army, state -- [universities should foster] appreciation of [the] necessity of limit[ing the] power of groups" (Innis 1980, 2.17). This belief in the university as a special haven for critical inquiry is perhaps why "some of his choicest epigrams of dispraise were reserved for those academics who, far from retaining a tentativeness about their subject bred of an awareness of limits, proceeded to expound final solutions" (Berger 1976, 103). Innis knew from personal experience how tempting it was for social scientists to accede to "appeals to utility and immediate application" to the detriment of the ceaseless task of understanding the nature and implications of such action (Creighton 1957, 130).

Grant explicitly asks the question of how one can make judgements about technology that are not biased by one's practical dependence on a vast array of technologies and the general approach of technological problem-solving in his discussion of the "will to technology" in his book *Technology and Empire* (Grant 1969, 31-32). He develops the idea further in *Technology and Justice* when he examines the comment of a computer scientist colleague that "the computer does not impose on us the ways it should be used" (Grant 1986, 19). He uses this comment to illustrate how difficult it is for even thoughtful people to avoid an unconscious bias towards adopting a technological problem-solving approach to most problems, including ethical issues. According to Grant, most people simply believe in the dogma that "all human problems can be settled by technical skill" even when "some of the dogma's formulations are shown to tend toward immoral practice" (Grant 1959, iii, vi).

In response to his colleague's remark he points out the simple fact that computer use is dependent on the existence of investment-heavy machines that require large commercial institutions for their production and hence "at the simplest factual level, computers can be built only in societies in which there are large corporations" (Grant 1986, 25). Also, computers have certain operating constraints, one of these being the need to classify data, and as Grant suggests, "It is the very nature of any classifying to homogenise" (Grant 1986, 23). He concludes that contrary to what his colleague would have him believe, computer technology does impose on its users how it should be used because it imposes a certain "destiny" on any society in which that technology is used. One cannot have computers without countenancing a certain kind of industrial development and one will, in using computers, necessarily become involved in actions of classification. The computer scientist's remark that the computer "does not impose" reveals that he is either ignorant of these social implications or that he believes that any difficulties, ethical or otherwise, that might arise can be dealt with without having to ethically question the uses of a computer. In either case, the remark illustrates an unquestioned faith that further technological activity will be sufficient for dealing with any difficulties that might arise from the application of computer technology and that technological innovations do not, in any meaningful sense, increase the burden of moral judgement that people must bear.

But Grant also insists that it would be a mistake to think technology is just the purview of technicians such as his computer scientist colleague. For him technology is a process in which all people participate through a multitude of everyday actions. The result is a "package deal" as he puts it (Grant 1986, 33). He questions how anyone can be expected to make judgements about technologies if one is so continuously engaged in the process of technological development. Grant expresses the dilemma that arises from this situation as follows:

> The result of this is that when we are deliberating in any practical situation our judgement acts rather like a mirror, which throws back the very metaphysic of the technology which we are supposed to be deliberating about in detail. The outcome is inevitably a decision for further technological development (Grant 1986, 33).

If the general approach of creative technological problem-solving itself becomes a standard and habitual way of responding to the problems created by such action, what practical action can be undertaken to face this problem that will not simply exacerbate the problem? According to Grant, in the process of bringing technology into ethical consideration one can even slip into a search for new technologies or techniques to address the problem of slipping too easily into a search for new technologies or techniques.

Like Grant, Innis also points out that an uncritically positive attitude towards a technological problem-solving approach has come to dominate in Western societies. As he puts it, "The form of mind from Plato to Kant which hallowed existence beyond change is proclaimed decedent. This contemporary attitude leads to the discouragement of all exercise of the will or the belief in individual power" (Innis 1951, 90). But he does not outline a programmatic way to address this problem. Innis' approach to communications studies simply attempts to make his reader aware of the possibility for such bias. Or as William Westfall describes Innis' approach to scholarship:

> The fact that one studies bias does not make one immune from it. Consequently, Innis incorporated into his analysis of bias a study of the specific context in which the observer existed and in which scientific analysis took place (Westfall 1981, 44).

But does this reluctance to make practical suggestions for dealing with technology and technological bias imply that it is completely impossible to escape their influence? As Grant attempts to put the problem succinctly, "technique is ourselves" (Grant 1969b, 137), or as he also describes our predicament, "All of us in our everyday lives are so taken up with certain practical achievements, in medicine, in production, in the making of human beings and the making of war, that we are apt to forget the sheer theoretical interest of what has been revealed" (Grant 1984, 37). Practical action tends to occlude the possibility for theoretical reflection and the result is that "we are called to understand technological civilization just when its very realization has radically put in question the possibility that there could be any such understanding" (Grant 1984, 34). McLuhan describes this fundamental predicament of modern life as follows:

> Man becomes, as it were, the sex organs of the machine world, as the bee of the plant world, enabling it to fecundate and to evolve ever new forms. The machine world reciprocates man's love by expediting his wishes and desires, namely, in providing him with wealth. (McLuhan 1964, 46)

How can we respond to the threat of technological dependency if the approach of developing a specific ethical or political program for offsetting its inherent tendencies is to be avoided?

What Innis', Grant's and McLuhan's analyses of technology seem to suggest is that there is a way of responding to any issue brought about by technological change that does not simply fall into the pattern of technological dependency. One must seek a proper balance between novel technological practice and the critical ethical suspension of one's participation in certain forms of such practice. In other words, when we are "deliberating in any practical situation," as Grant describes this fundamental choice, we can either choose the route of "technological development" or we can critically reject some form of technological development in which we are participating. McLuhan suggests that such a fundamental choice is always a possibility when he states that "we can, if we choose, think things out before we put them out" (McLuhan 1964, 49). Innis seems to describe such a fundamental possibility when he notes that "civilization [is] a struggle between those who know their limitations and those who do not" (Innis 1980, 5.33). Their analyses of technological dependency all seem to indicate that when seeking to respond ethically to practical problems in which technology has played some part the *choice is always between innovation and discrimination about innovation*. Their critical theories of technology argue for a more balanced application of these two fundamental approaches.

The source for this fundamental choice is in the inherent nature of the technological process to create new problems, or "irritants," and new forms of disequilibrium in power. Since it is impossible, according to Innis, McLuhan or Grant, that a state of technological completion can ever be achieved, any new technology will always bring with it a certain amount of harm in addition to the benefits it brings, harm that will also be distributed unevenly in a society. Thus the technological process perpetually creates new technological issues that can be responded to either by seeking some new form of technological power or by way of the critical rejection of some problematic technology. Or as McLuhan describes this dynamic:

> Response to the increased power and speed of our own extended bodies is one which engenders new extensions. Every technology creates new stresses and needs in human beings who have engendered it. The new need and the new technological response are born of our embrace of the already existing technology—a ceaseless process (McLuhan 1964, 183).

The ongoing potential for bias toward technological action to respond to novel problems is based in this dynamic. Since we are talking about two fundamentally different categories of possible response to any practical difficulty in which technology plays some part, unless the human capacity for action is unlimited, then one's life will always have to consist of a certain ratio between these two kinds of action. But it is obvious that without some conscious effort to maintain this ratio at some appropriate level, the ratio could skew dramatically in one direction or the other. And the strongest tendency will be towards the technological side because technological activity always involves us either in habitual ways of acting or in the intense pursuit of such ways, which itself can become a habitual response. And technological action not only creates an ongoing need for such action it can, by its very nature, help denude one's ability to engage in thoughtful reflection on, and judgement of, such need. All technological action can involve a largely unconscious self-reinforcing tendency in virtue of the fact that such action always involves its own distinctive way of resolving the problems that it helps produce. Thus, this way can compete with alternative ways of addressing such problems, such as the simple rejection of specific technological actions.

According to Grant, the activity of reflecting on the ethical import of our technological choices can therefore be increasingly excluded from a life dominated by technology. As he puts it, "as an end in itself, [technology] inhibits the pursuit of other ends in the society it controls" (Grant 1959, vii). There is a very simple reason for this tendency. According to Grant, technology involves such a tendency because it cannot itself encompass contemplation and deliberation about ends. It cannot encompass these types of activity because it is the active pursuit to satisfy specified ends, taken as already given. It can be coupled with the activities of contemplation and deliberation about ends, but it need not, and this inherent possibility of disjunction means that not only can it potentially escape ongoing ethical scrutiny, it can displace such activity.[i] Innis describes this inherent tendency as follows: "Constant changes in technology . . . increase the difficulties of recognizing balance let alone achieving it" (Innis 1951, 140). Or, as he notes about writing in particular, "absorption of energies in mastering the technique of writing left little possibility for considering implications of the technique" (Innis 1951, 9). McLuhan cites in at least five places Alfred North Whitehead's statement: "The greatest invention of the nineteenth century was the invention of the method of invention" (McLuhan 1962, 45, 176; 1995a, 187; 1995b, 383; 1968, 15). Coupling this notion with his understanding of the inherent nature of all technologies to escape our critical awareness indicates that he felt it equally important to be critically aware of our use of the technological problem-solving approach. For all three of these Canadian critics of technology it would appear that if one were unwilling to question one's commitment to habitual forms of technological practice, including the general approach of technological problem-solving, one would fail to fully meet the ethical challenge of technology.

In line with their call for greater skepticism about innovation, it is not surprising that they eschewed calls for novel ethical approaches to meet the challenges of our technological future. They suggest instead that we might already be equipped well enough with appropriate ethical tools and that what is lacking is simply a willingness to put these tools to use in the restraint of specific technological activities. Perhaps this emphasis on the strength of tradition is why many commentators have considered them to be impractical when it comes to saying something to address the questions of our technological future. The following citations from various commentators certainly suggests that this was a common disappointment with their work: "Innis never believed in an easy dissolution of such biases, especially as he perceived more clearly their operation in our own time, nor did he advance any special vision of the future" (Crowley 1981, 240-41); "What McLuhan never saw from looking at television was what he once knew perfectly well . . . the mechanical bride marries us to the power of the state and its industrial economy. But McLuhan preferred not to lift the veil [of power]" (O'Neill 1981, 13); Grant "ultimately refuses to follow through on the hard implications of his philosophy" (Kroker 1984, 49); "Grant has been charged with providing few solutions to the profound problems he raised. To 'lament,' after all, is to imply that it is already too late to do much . . . One might wish that he had been able, or had been more inclined, to couple his deep analyses and profound faith with plans for action" (Babe 2000, 205-206). According to these commentators one should expect some kind of innovative theoretical approach to the ethical and political challenges of technology from such reputedly insightful critics of our technological age.

That no such novel approaches were proffered has puzzled some commentators, but the programmatic silences of Innis, McLuhan and Grant make sense in light of their discussions of the dangers of technological dependency. Part of their message might be that we should be cautious about experts and skeptical about the promises of novel ethical or political reform programs and simply get on with the task of making conscious ethical choices about the technologies in our lives with the ethical resources we already have. As Arthur Kroker has pointed out about McLuhan, "Over and over again in his writings, McLuhan returned to the theme that only a sharpening and refocussing of human *perception* could provide a way out of the labyrinth of the technostructure" (Kroker 1984, 64). As Grant puts it, "those of us who at certain times look to grasp something beyond history must search for it as the remembering of a negated tradition" (Grant 1969b, 137). Whereas Innis writes:

> It is to be expected that you will ask for cures and for some improvement from the state of chaos and strife in which we find ourselves in this century. There is no cure except the appeal to reason and an emphasis on long-run considerations--on the future and on the past. (Innis 1977, 5)

The implication of the ethical critiques of technology of Innis, McLuhan and Grant is that one should not avoid actually making choices about one's technological actions because one is preoccupied with the development of improved ethical or policy tools.

This idea is exemplified in the lives of Innis, McLuhan, and Grant. They practised what they preached. As one commentator notes of Innis:

> His own bias, as he so often stated, valued a culture characterized by balance, order, and the oral tradition. His analysis of the problem and his attachment to these human, non-technological values set a course that a number of Canadian nationalists would follow. He beheld the decline and fall of a meaningful culture, and he was bitter as he faced defeat. One can hear the echoes of his lamentations in the work of George Grant, Donald Creighton and Dennis Lee. (Westfall 1981, 47)

Innis could make comments like the following because his stance towards technology encourages not only innovation but also the possibility of the critical rejection of some innovations:

> Mass production and standardization are the enemies of the West. The limitations of mechanization of the printed and spoken word must be emphasized, and determined efforts to recapture the vitality of the oral tradition must be made. (Innis 1950, 168)

It is possible to see in Innis' work strains of determinism, and therefore, the rejection of any possibility of actively seeking a balance between the various technological forces that allow for the stability of empires (Duffy 1969, 16). It is also possible to see in his work a call to create novel technological forms in an attempt to achieve the type of balance he felt could be found in the civilization of Byzantium (Innis 1951, 117). Both these perspectives fail to fully capture the position of Innis because his position also encompasses the possibility for the critical rejection of technologies, such as the rejection of print in favour of face-to-face discourse. As Dennis Duffy observes, "his own bias, he proclaimed, was for the oral tradition, which he saw involving 'personal contact and a consideration for the feelings of others'" (Duffy 1969, 16).

McLuhan was also willing to consider the possibility of the critical rejection of technologies. For instance, he states that "The technology of the photo is an extension of our own being and can be withdrawn from circulation like any other technology if we decide that it is virulent" (McLuhan 1964, 193). There is a desperate quality to the writings of McLuhan near the end of his life, well documented by his biographers. As Marchand characterized this state, in his last years McLuhan resigned himself to the "grim role of the seer who is sometimes derided, sometimes petted, but never heeded" (Marchand 1990, 228). But this desperation did not stop him from taking action to fight those aspects of modernity he disliked. As Marchand also notes: "He publicly opposed increased congestion in the heart of the city, whether in the form of new expressways or high-rise apartment buildings, which he particularly despised" and that he "disliked automobiles on principle" (Marchand 1990, 89). It is well known of McLuhan that he could sometimes present himself as an apologist for technological change (Marchand 1990, 169). However, Marchand suggests that "he was also in the habit of defending his intellectual flank by frequently insisting that his outlining the features of the new media ought to have inspired everyone with sufficient revulsion to avoid them" (Marchand 1990, 170). The apparent espousal of technological change has brought some of McLuhan's followers to conclude that McLuhan favoured unrestricted experimentation with new technology. Derrick De Kerckhove, for example, interprets McLuhan as championing a form of techno-fetishism:

> Where other cultural observers might have cited forces of marketing, McLuhan saw in this phenomenon a purely psychological pattern of narcissistic identification with the power of our toys. I [De Kerckhove] see it as proof that we are indeed becoming cyborgs, and that, as each technology extends one of our faculties and transcends our physical limitations, we are inspired to acquire the very best extension of our own body. (De Kerckhove 1995, 3)

However, others besides Marchand have argued that McLuhan is perhaps more of an old-fashioned moralist, and even Luddite, than De Kerckhove is willing to acknowledge. As Sam Solecki notes about McLuhan: "He told one reviewer that he was a conservative and hated all change, but given that change was inevitable he was damned if he was going to let it roll over him" (Solecki 1981, 4). Such an interpretation of McLuhan means taking seriously his statement that "we can if we choose, think things out before we put them out." It means considering the possibility, as Marchand recommends, that some of McLuhan's seemingly more positive statements about technological change were meant primarily as rhetorical overstatements aimed at eliciting one's skepticism (Marchand 1990, 169). For McLuhan, stopping the use of a technology quite clearly does not commit one to the complete rejection of all technology but to an intelligent readjustment of one's technological choices. He states that the "amputation of such extensions calls for as much knowledge and skill as are prerequisite to any other physical amputation" (McLuhan 1964, 193). Rejecting a technology may mean filling the space left in one's capabilities with another existing technology or it may mean simply choosing to do different things altogether. "To resist TV," McLuhan writes, "one must acquire the antidote of related media like print" (McLuhan 1964, 170).

If the positions of Innis, McLuhan and Grant leave them open to accusations of vagueness and impracticability, this may be intended, for their positions point to the conclusion that the offering of a novel ethical or policy program is one of the least helpful things one could do for a society hooked on seeking novelty. Instead, we must look to what they refused to do to get a proper grasp on their approaches to charting a proper course into the technological future. We can see a critical approach to technology in Grant's ethical criticism of abortion and the growing influence in the humanities of the scientific paradigm of research, and in his call for the recovery of ancient political philosophy (O'Donovan 1984, 73). For Innis, a critical approach can be seen in his misgivings about the expansion of "the price system" and his battles against the "mechanization" of knowledge and the increasing tendency of economists to become consultants to governments and business (Kroker 1984, 118-121). He frequently criticized social scientists for being too enamoured with "elaborate calculating machines" and "refinements in mathematical techniques" (Innis 1951, 86). He was skeptical about whether the new media of communication would contribute to improving human awareness and understanding, such as when he states in the following note from the *Idea File*: "Improved communication smothers ideas and restricts concentration and development of major ideas. Mechanization and sterility of knowledge [result]" (Innis 1980, 2.7). Innis, like McLuhan and Grant, had a certain degree of anti-reformism in his approach to technology. How else can one make sense of a comment such as this: "Belief in [a] prosperity cult [is a] part of increased advertising--[the] emphasis [is always] on [seeking a] better world and [the] avoidance of problem[s]" (Innis 1980, 2.3). The fundamental point each makes through his programmatic silence but willingness to engage in the critical rejection of specific modern trends, is that one's response to the challenges of technology should not become overly focused on finding some radically new way of ameliorating the effects of technological change.

Innis, McLuhan and Grant each argue that such technological proposals for political action are not enough and that they can easily become mere public relations exercises that can distract us from wrestling with our own individual contributions to the technological causes of many social ills. Innis suggests that modern means of mass communication promote such a tactic when he states that "[modern politics is characterized by a] necessity of stressing continuous political and legal change as a device for dominating news" (Innis 1980, 5.24). Even guided by the best intentions, some calls for systematic political reform can have the unforeseen consequence of reinforcing technological dependency by deflecting attention from the need for individuals to re-examine their technological practices. What is required is that in addition to creating innovative political ways of managing the effects of technological change one must also consider the possibility of simply eschewing certain technological actions that one undertakes as an individual that contribute to the creation of certain social issues. As McLuhan expresses this dual ethical responsibility: "What we seek today is either a means of controlling these shifts in the sense ratios of the psychic and social outlook, or a means of avoiding them altogether"

(McLuhan 1964, 70). Ethically addressing technology should not only involve seeking ways to control the effects of technological change. It must also involve the critical analysis of the actual negative effects of one's own technological choices.

The life of renowned architectural critic, city planner, and environmentalist Jane Jacobs provides a good example of someone attempting to live a life in which technological action is properly balanced by action focused on the reconsideration of particular technological activities. Jacobs is perhaps more renowned for the actions she has rejected than those which she has endorsed. She was "instrumental in preventing the wholesale devastation of neighbourhoods [in Toronto] by various misguided crosstown expressway proposals" (Saunders 1997, C20), such as the Spadina Expressway.[ii] One commentator notes that she "rejected the prevailing credo of wide highways, big [housing] projects and single-purpose zoning" (Hume 1997, F5). As she herself recounts, "When David Crombie was mayor he consulted me about getting housing downtown. . . . One of the biggest problems we had to deal with was old bylaws" (Hume 1997, F5). She also has commented that "if the car has become a source of evil, it is because it has been made to fill too many niches." And as she goes on to recount: "I was born and raised in a suburb, when I went to New York at the age of 18, I was enchanted. I've never been tempted to go back to live in a suburb" (Hume 1997, F5). Her main impact has not been in espousing a specific political program but rather in rejecting and advocating for the rejection of specific technological practices. As Alan Littlewood, a Toronto City planner put it "Jane was never prescriptive. There were no formulas, no 'how-to' books" (Hume 1997, F5).

Innis, McLuhan, and Grant were most likely silent on the question of how to fashion public policy for the control of technology because their understandings of technology involve seeing such a project as most likely being a mere manifestation of technological habit. Their response to this conclusion is a case of the medium being the message. The message of their silence is that we should get on with the task of ethically questioning our technological habits. This conclusion suggests that the hope of those like Andrew Feenberg, who wish to develop some kind of "politics of technological transformation" or some "structural basis for understanding the operations in which the dominated might resist domination" (Feenberg 1991, 13, 73) might be at best naïve, and at worst, unhelpful.

In fact, Feenberg's discussion of the views of Heidegger, Marcuse, Foucault, and Ellul on technology, and his concerns about their "fatalism" and in particular the political "impasse" (Feenberg 1991, 73, 75) that he finds in Heidegger's work, seem to parallel my own analysis of the thought of Innis, McLuhan and Grant. The apparent pessimism to which these thinkers seem prone could indicate that they too may have held a belief that the thoughtful rejection of specific technological actions using the ethical tools one already had on hand could be an adequate response to the ethical challenge of technology. In other words, these other technological theorists might have agreed with Iain Thomson's suggestion to Feenberg that "the critical theorist of technology can learn much from the Amish, who are no 'knee-jerk technophobes,' but rather 'very adaptive techno-selectives who devise remarkable technologies that fit within their self-imposed limits'" (Thomson 2000, 208). Innis, McLuhan and Grant all point toward the need to include such limits in one's life. That they remained largely silent about how to respond systematically to technology's challenges indicates the extent to which one might have to go in controlling habitual technological response. One can find in their silence a demonstration of the clear alternative to the technological approach--the simple thoughtful rejection of a particular technological habit. Their analysis of technology suggests that a proper response to technologically originated issues, is to understand the limits of our ability to resolve technological dilemmas through technological problem-solving and to recognize the compelling moral necessity for people to also exercise personal responsibility when it comes to their own mundane technological choices. In other words, we should not always rely first and foremost on novel legal mechanisms, political programs, ethical theories or any other such "plans for action" to resolve the ethical dilemmas raised by technology, but realize that technology must also be responded to by the ethical judgement of human individuals. Such a position is similar to one increasingly suggested by some environmentalists in regards to certain environmental issues, such as climate change. Their calls for people to make radical changes in lifestyle echo the suggestion of Innis, McLuhan and Grant that there may be instances in which technology creates challenges that can only be responded to adequately by individuals also making moral judgements about their own technological activities.

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Notes

[i] As Grant states, "Perhaps [as moderns] we are lacking the recognition that our response to the whole should not most deeply be that of doing . . . but that of wondering or marvelling at what is, being amazed or astonished by it, or perhaps best, in a discarded English usage, admiring it" (1969a, 35).

[ii] McLuhan worked with Jacobs in the resistance to the expressway, which Jacobs recounts in *Who Was Marshall McLuhan? Exploring a Mosaic of Impressions* (Jacobs 1994, 101-102).

Report from the Field: Skipping Hard-Wired Technology

Olga Nunn

Fig. 1: Pasha Zagorodnyke.

The following article is derived from my research in Ukraine on the 11th of July 2005. It discusses mobile phone use and how their technology serves the population that uses them. It also briefly considers how mobile phones arrived in the Ukraine.

The basic concept of a mobile phone can be traced back as far as 1947 in the U.S. Researchers at Bell Labs developed the concept of mobile car phones used by police. However, the technology to implement this concept was not available at the time. The first modern portable handset was not invented until 1973. Martin Cooper, who had previously worked for Motorola, invented the first modern portable handset. More importantly, the commercial use of a mobile phone in America was slowed by the Federal Communications Commission (FCC) regulations. Only in 1982 did phone service become commercially available in the United States. (http://inventors.about.com).

Further technological developments have led to increased capabilities and further adaptations of cellular phone service in America and Europe. There is now worldwide demand for mobile phone service.

In the Ukraine there are over twelve mobile service providers, including UNC, Sim-Sim, Ace&Base, and UNI, to name a few. Affordable tariffs attract more users. One of the biggest Ukrainian mobile operators, Actelit, has 1,200 cell towers, with plans for continued growth. (http://www.mobilnik.org.ua/info/operators.php) This demand is partly driven by the fact that rural Ukraine telephone infrastructure is largely underdeveloped.

For example, in one small hamlet in Ukraine, with a predominantly elderly population, the only way to contact family members living elsewhere is by mobile phone. Pasha Zagorodnyke, pictured in Fig. 1 above, relies heavily on mobile phone service to stay in touch with her son, who lives in a city about 300 km distant. She is not the only user of this technology. All the villagers say it is a godsend and they all worship it. Some have commented to me that they could not live without it now. Without the mobile phone it would not be possible to get in contact with their families who left for the major city of Ukraine, Kiev, in search of better opportunities.

Most houses are empty, owners passed away. They have left everything ready to move in and live. Once a blooming hamlet, this small village has become an isolated place for older and more vulnerable occupants. They have nowhere else to go. The hamlet became less attractive after the fall of the Soviet Union and government farming. For an older generation, growing vegetables and keeping animals is the way to survive.

There is no hospital, school, or post office, no gas or water mains. The nearest amenities are 16 km away, which for the elderly is an impossible walk. Every villager comes to Pasha Zagorodnyke to make a call from time to time. In compensation, they bring whatever they can, often something from their garden such as a bowl of fruit, vegetables, or milk. For these people, mobile phones serve as a lifeline, a dream come true.

To my astonishment, the elderly of this hamlet are using the most advanced technology to communicate, but their social behavior has not changed for decades. In this respect the mobile phone bridges vast distances and provides for 'emergency use.' The occupants of this hamlet doubted whether the infrastructure would ever be laid for telephones. But, the mobile phone circumvented this need and answered their prayers. It is no longer necessary for them to have a "land line" infrastructure. A single call can provide hope that someone would come and see them – a daughter, son, grandchildren, niece or nephew. They are always happy to see people. When I was there they treated me like a goddess. I was given the best food, bed, and most of all a warm welcome.

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http://inventors.about.com/library/weekly/aa070899.htm (9/26/2005)

http://www.mobilnik.org.ua/info/operators.php (9/26/2005)

The Matter of Technology: A Review of Don Ihde and Evan Selinger (Eds.) *Chasing Technoscience: Matrix for Materiality*

Peter-Paul Verbeek
University of Twente, The Netherlands
p.p.c.c.verbeek@utwente.nl

Don Ihde and Evan Selinger, eds. 2003. *Chasing Technoscience: Matrix for Materiality* Bloomington & Indianapolis: Indiana University Press.

Chasing Technoscience embodies a trajectory that every PhD student, and everybody interested in Science and Technology Studies and the Philosophy of Science and Technology, should follow. It interviews some of the most important scholars in the field, reads some of their most recent texts, critically analyzes their positions and relates them to each other. The book can be considered an 'advanced introduction' to the interface between empirically oriented research of science and technology on the one hand, and the philosophy of science and technology on the other.

The scholars chosen to represent the state of the art in these fields are Donna Haraway, Don Ihde, Bruno Latour, and Andrew Pickering. The book consists of two parts. Part One contains an interview with and an article by each of these four scholars. Part Two contains six chapters in which these four positions are analyzed, annotated, compared, and criticized. Although the second part is certainly worth reading, the first part of the book is the most exciting. This is especially true for the interviews, which offer interesting new insights in the work of the authors discussed.

Chasing Technoscience aims to give special attention to the importance of materiality for understanding science and technology and their cultural roles - the book's subtitle even reads "Matrix for Materiality" - but beside materiality there are two other themes running through the book: the relation between empirical and philosophical research; and the role of normativity in STS and the philosophy of science and technology.

An important theme in the book is the relation between philosophical investigation and empirical research. The book opens with a profound and entertaining interview with Latour, in which he explicitly characterizes his work as 'empirical philosophy.' Whereas classical STS defined itself in opposition to philosophy – disparagingly indicating it as 'armchair philosophy,' devoid of any contact with the reality it attempts to analyze - Latour defines himself as a philosopher who "tries to get at classical philosophical questions through the methods of fieldwork and case-studies." He states, albeit somewhat ironically, that "deep down," his "real interest is in metaphysics." Latour adds that he practices metaphysics in an empirical way, by studying "the different truth production sites that make up our civilization": science, technology, religion, and law. For him, metaphysics is not the building of fundamental categories but to "monitor the experiment with which the world makes itself" in order to see "how all the ingredients of the world – space, time, agency – of what will compose a normal metaphysics are actually redone locally." This empirical work does not add to a systematic 'philosophy.' As Latour says: "I produce books, not a philosophy." His interest is with the specific field of reality he is studying, not with the frameworks to study these fields.

All authors in the book work on this edge of empirical research and philosophical analysis, with Latour being closest to empirical research and Don Ihde being the least empirically oriented. Ihde's (post)phenomenological work on the mediation of perception and the role of instruments and image technologies in scientific research does take concrete practices of 'truth-making' as its objects of research, but rather than invoking ethnographical methods Ihde applies and expands phenomenological notions like intentionality, embodiment, and hermeneutics to analyze the practice of scientific imaging. Ihde is not primarily interested in doing justice to the actors, but in understanding why phenomena are given in specific ways in specific circumstances, relating the ways in which things are given to the technologies that help humans perceive and interpret them.

A second theme in the book, as the book's subtitle expresses, is materiality. Actually, not simply materiality is the main issue here, but, more broadly, ways to get beyond human-centricity and subjectivism. After decades of contesting realism and objectivism, by showing how realities and objectivities are socially constituted and defined, it seems that time has come to make the opposite movement and show how the social is materially mediated. Materiality is no blank projection screen for human interpretations, but plays an active role in our technological culture. Science and technology should not only be understood as the *outcomes* of social processes, but also as their '*input*.'

The main discussion here concerns material agency: are human beings the only entities able to 'act'? Latour refuses to make an *a priori* distinction between humans and 'nonhumans' but rather considers this distinction a specific (modernist) way of ordering reality. Haraway's entire work aims to deconstruct the nature/culture distinctions that pervade our thinking, as her work on cyborgs shows, as well as an intriguing text on dogs as nature/culture hybrids, which is included in the book. Nature (with its 'objects') and culture (with its 'subjects') cannot be had separately, and each mixture of them ultimately is a political configuration.

Pickering, however, holds on to a form of asymmetry between humans and non-human entities. He understands human beings in terms of their intentionality, which he loosely defines as 'goal-directedness.' This asymmetry between subject and object, however, should not be seen as an *a prori* distinction but as a deliberate choice to be better able to describe reality. Also Ihde refuses to give up the modernist subject-object distinction. He considers it more fruitful to focus on the ways in which subjects and objects interfere and mix. He does not want to distance himself from humanist *values* but does consider his work post-humanist in the sense that the primacy of the 'pure' human subject needs to be given up and replaced with a human subject which embodies all kinds of technological objects. The book makes explicit interesting differences in positions here, but it would have been even more interesting if these differences were analyzed and unraveled further.

The third theme in the book is normativity. In STS, this theme is receiving ever more attention, as well as in the philosophy of technology. Again, the book lays bare interesting views of normativity in science and technology. Latour approaches morality as an object of study just like any other object: it is in the things to be studied, and the vocabulary with which to describe it needs to be obtained as much as possible from the actors themselves. Against this descriptivist approach, Donna Haraway takes a normative starting point in her analysis: feminist engagement. She stresses that she regrets that in STS circles, her Cyborg Manifesto is often read without adequately recognizing its feminism. Pickering, in his turn, links normativity to aesthetics, and expands his recent work on 'becoming' (as opposed to 'being') to a "politics of becoming," which is a "politics of experiment," "continually trying this and that without pretending to know the outcomes in advance."

The humorous article "Do You Believe in Ethics? Latour and Ihde in the Trenches of the Sciences Wars," by Aaron Smith, in the second section of the book, deals explicitly with normativity. This article perfectly illustrates the relevance of an ethical perspective in contemporary technoscience studies, but also shows how difficult it is to incorporate state-of-the-art insights, like those in nonhuman agency and post-subjectivism. In his article, Smith attempts to extend the work of Latour and Ihde to ethics. He shows how Ihde's work makes it possible to conceptualize that human intentionality can be operative 'through' embodied technologies, and how Latour does away with an exclusively human interpretation of intentionality, attributing agency to chains of actants rather than a 'prime mover.' Smith concludes that Latours work is problematic with regard to ethics: "The consequences of rejecting the limitation of prime mover status to humans would be to take the implausible position of attributing prime mover status to non-humans such as automatic doors, guns, automobiles, and atomic reactors."

Yet, this criticism passes over precisely what is at stake in much state-of-the-art philosophy of technology and technoscience studies: the move beyond subjectivism and humanism, and toward materiality. Just like Latour's work on nonhuman agency, Ihde's work on the hermeneutic roles of technologies does not only show that *human* intentionality can be 'stretched' over artifacts, but also that *artifacts* have an 'intentionality' to shape human decisions and actions, without this role having been explicitly delegated to them by their designers or users. In order to understand ethics and morality in our late-modern technological culture, we need to move beyond the strict modernist separation of subject and object, which causes our current problems with understanding the mediating roles of technologies and the mediated character of human actions in terms of morality. If we hold on to the autonomy of the human subject as a prerequisite for moral agency, we will never be able to understand the moral character of the ways in which our actions are co-shaped profoundly by the technologies around us. Therefore, a better connection with the other themes that run through the book – the possibilities of an 'empirical philosophy' and the move beyond subjectivism – could have informed a richer perspective on the moral character of technoscience than holding on to 'prime movers' which eventually need to be purely human.

Nevertheless, the variegated and profound treatment of these themes makes *Chasing Technoscience* a very interesting and engaging book about some important state-of-the-art themes in STS and the philosophy of science and technology. If the book has identified a correct image of the state of the art in the field, there are some exciting years ahead of us.

Towards a Postphenomenology of Artifacts: A Review of Peter-Paul Verbeek's *What Things Do*

Evan Selinger
emsgsh@rit.edu
Rochester Institute of Technology

Verbeek, Peter-Paul. 2005. *What Things Do*. Trans. Robert P. Crease. PA: The Pennsylvania State University Press.

What are artifacts? As the "technological developments of the past century have made this question more pressing than ever," Peter-Paul Verbeek's book, which attempts to provide a definitive answer, is relevant to, and deserves to read by, scholars throughout the humanities as well as the disciplines concerned with issues of design and engineering (1). Moreover, since Verbeek contextualizes his contemporary concerns against an explicit historical background, that is, since he constantly probes into why the "questions posed by the classical philosophy of technology deserve a new set of answers," his ruminations on the significance of things can appreciated by students of varying levels—even ones with limited philosophical exposure (3).

Overall, Verbeek's text is *ambitious* in scope and replete with *rigorous* interventions. Because it is *clearly written* and *coherently organized*, every single chapter proves rewarding. This positive experience became amplified in the book's concluding remarks. There the work as a whole coheres programmatically. It even has the potential to inspire one to perform complimentary aesthetic and moral inquiry into material cultures.

To concretize these observations, it can be said that Verbeek's project is *ambitious* because he does not aim to merely survey canonical sources or rehash well-trodden meta-philosophical tirades about the denigration of materiality and embodiment in the Western philosophical tradition. Rather, he attempts to reformulate the very enterprise of the philosophy of technology as "postphenomenology"—a perspective in which artifacts mediate the relation between human beings and their world so thoroughly that our ability to understand "subjectivity" and "objectivity" depends upon our ability to grasp how artifacts reduce and amplify the "forms of contact" that relate people to one another and to nature. To accomplish this goal as a charitable reader requires, at the very least, two rare virtues: diligence and the ability to appreciate that the relation between novelty and continuity is complex. Recognizing these points, Verbeek sets out to: (1) discern the limits of traditional approaches to understanding and assessing technology, (2) display sensitivity towards phenomenology's underlying ambitions even in those instances where the motivating goals have not been fully satisfied, and (3) demonstrate that some core phenomenological insights remain pertinent even in those instances where the traditional phenomenological vocabulary and thematic orientation require alteration. For these reasons, Verbeek's *modus operandi* is dialogical engagement with traditional existential and hermeneutic discussions of method, operative concepts, and subject matter; abandoning intellectual history and beginning anew—neo-Cartesian impulses expressed routinely in some iconoclastic Anglo-American philosophy and Science and Technology Studies literature—are not considered viable options.

Verbeek's discussions are *rigorous* in that he not only provides a thorough exegesis of core ideas exposited by Karl Jaspers, Martin Heidegger, Don Ihde, Bruno Latour, and Albert Borgmann, but he also articulates subtle and provocative criticisms of (some of) their primary epistemic, ontological, and normative commitments. In line with recent trends, the pioneering works of Jaspers and Heidegger are depicted as historically important, but, ultimately, as emblematic of failed transcendental projects:

Close inspection reveals that Jaspers and Heidegger failed to support their analysis of technology adequately. They reduced technology to its conditions of possibility and then proceeded as if what they said about those conditions applied to technology itself…Both philosophies appear governed by what one might call a "transcendental fix" (100).

Although Verbeek is not the first person to provide this diagnosis, he happens to articulate it with a rare level of detail. Similarly, although he is not the first person to turn to Ihde, Latour, and Borgmann for the purpose of locating conceptual resources that would allow the concerns that animated the transcendental approach to "do justice to the concrete empirical reality of technology," he brings a perfect balance of reconstruction and assessment to their core ideas. (Here, it is worth highlighting that even though Jaspers no longer occupies center stage in philosophy, Verbeek provides a compelling demonstration of the value of reflecting on his views on "mass existence." In light of the evocative links that Verbeek makes to the Frankfurt School, a revivable of Jaspers' thought—perhaps one akin to the recent returns to Henri Bergson and Hans Jonas—may be facilitated by this publication.)

With the assistance of Robert Crease's meticulous translation, Verbeek's text maintains *clarity of presentation* throughout. Considering the amount of technical vocabulary that Verbeek engages with, as well as his desires to (1) interface different theoretical traditions (which, in turn, requires relating Latour's unique prose to the more familiar phenomenological idioms) and (2) articulate a new conceptual framework for the philosophy of technology, this is a significant accomplishment.

Finally, Verbeek's *coherent organization* enables his core thoughts to be articulated in a compelling manner. His discussions of Ihde, Latour, and Borgmann all benefit from the earlier analyses of Jaspers and Heidegger. Indeed, the explicit and subtle shifts in orientation provided by the former simply could be not explored adequately without having first presented a thorough analysis of the latter. New conceptions of materiality and agency, as well as different ways of conceiving the relation between empirical and transcendental analyses, only make sense against a carefully circumscribed historical horizon. And, perhaps most importantly, Verbeek's last chapter, "Artifacts in Design," provides the reader with a concrete sense of how to "apply" the insights of the revised philosophy of technology. Here, Verbeek turns to industrial design and clarifies how postphenomeonological considerations are well-suited for helping us to understand how and why people can become "attached" to artifacts. His analysis of the ecological ambitions of the Dutch organization Eternally Yours is an exemplary instance of how philosophers of technology could, and indeed should, make the "empirical turn."

In light of the above observations, it is hard to imagine how someone could finish this text and fail to understand what central concerns have animated the classical philosophy of technology, or why the field is revisiting its traditional assumptions about agency, alienation, causality, classification, and meaning. Likewise, it is almost inconceivable that someone could engage with Verbeek's "principles" of analysis and still maintain that the general conceptual framework provided by the philosophy of technology is less valuable than the discursive frameworks found in the more specifically attuned and applied branches of technological analysis (e.g., medical ethics, biotechnological assessment, *et cetera*). For these reasons, the book solidifies Verbeek as a dominant principal in the field.

Having now complimented Verbeek on all of his admirable accomplishments, it only seems fair to highlight the one dimension of his analysis that I disagree with. In the chapter "Postphenomenology," Verbeek writes as if he is not only providing a *précis* of what this research program means to Ihde, but that he is also expanding upon ground that Ihde pioneers in a preliminary fashion.

> In the introduction to *Postphenomenology*, he [Ihde] says that his philosophical orientation includes a strong sense of 'proliferating pluralism' and the loss of centers and foundations, but he does not then go about showing what a reformulated phenomenology might look like under those conditions. This is the aim of the more radical interpretation of phenomenology that I am proposing (113).

This claim should pique the reader's interest because Ihde figures prominently throughout Verbeek's book. One not only can find the influence of Ihde's style of interpretation when Verbeek analyzes the godfathers of Jaspers and Heidegger, but Ihde's presence remains, in explicit and subtle ways, when he addresses more contemporary thinkers and issues. Thus, the idea that Verbeek might be clearer about what a "reformulated phenomenology" would look like than Ihde has been is intriguing—particularly, if what is presented is truly "more radical."

Despite this tantalizing announcement, Verbeek essentially restates claims that Ihde has already made. Specifically, in the pages that immediately follow, Verbeek appeals to Ihde's concepts of "technological intentionality" and "multistability." With respect to the latter, Verbeek reiterates Ihde's insight that "artifacts can only be understood in terms of the relation that human beings have to them" (117). He even illustrates this idea by referencing Ihde's paradigmatic example of the multiple visual possibilities that can arise by looking at Necker cubes in different ways and with different expectations. By proceeding in this manner, the reader is left with the impression that since Verbeek endorses Ihde's version of multistability, he must surely be expanding upon Ihde's conception of technological intentionality.

According to Verbeek, Ihde's concept of technological intentionality refers to the "inclination or trajectory that shapes the ways in which things are used" (114). Fountain pens, for example, typically allow users to write slower than word processors do; as a consequence, they "allow the user to think over the sentence several times while composing" (114). What this account of technological intentionality does not address, Verbeek claims, is the more radical view that is illustrated by Landgon Winner's discussion of the politics of artifacts

> The postphenomenological perspective described above [the Winner example] allows a more radical extension of Ihde's concept of "technological intentionality." The "intentionality of artifacts" consists of the fact that they mediate the intentional relation between humans and the world in which each is constituted. When human beings use an object, there arises a "technologically mediated conception of intentionality," a relation between human beings and the world mediated by a technological artifact (116).

In light of how this passage is worded, the following question therefore arises. Has the matter in which technologies can "codetermine" how "subjectivity and objectivity are constituted" really been articulated by Ihde with as limited attention as Verbeek suggests?

Like Verbeek, Ihde has also referenced Winner's example of the Robert Moses bridge design. Where Ihde seems to fall short, therefore, is at the conceptual level. In this context, Verbeek points out a putative difference between different phases of Ihde's philosophy of technology.

> By saying that mediation is located "between" humans and the world (as in the schema I-technology-world), Ihde seems to put subject and object over against one another, instead of starting from the idea that they mutually constitute one another. His analysis appears to suggest that he takes as a point of departure humans already given as such and a world already given as such, in between which one can find artifacts. Ihde does not address this problem in *Technology and the Lifeworld*, though it gnaws at the roots of his approach to the phenomenology of technology. Only later, in *Expanding Hermeneutics*, does he make clear—completely in line with the postphenomenological perspective—that subject and object are mutually interrelated, but he does not connect this thought with his earlier analysis of human-technology relations. The phenomenological insight that subject and object are mutually interwoven thus males it necessary to supplement Ihde's analysis of technological mediation (129).

Although Verbeek peppers this passage with qualifiers ("seems to put" and "appears to suggest"), he renders a decisive judgment. Like the later Maurice Merleau-Ponty who needed to develop a notion of the "chiasm" to get beyond his earlier subject-object phenomenology, we are informed that the philosophy of the later Ihde also tries to move beyond his earlier reliance on subject-object language and thinking.

I don't find Verbeek's interpretation of Ihde to be defensible on this point. He makes far too much Ihde's linguistic reliance on terms such as "I" and "world" and gives far too little consideration to what Ihde means when he uses these terms. Due their historical sedimentation, the terms may evoke traces of vestigial Cartesiansim. Ihde, however, uses them in a manner that focuses on connections, links, and bonds. More specifically, Ihde's phenomenology has never been about experience as such, but rather, it has always focused on the *relations* that make experience meaningful and possible. As Verbeek is himself aware, Ihde has always tried to avoid the subjectivist and objectivist trends in philosophy; what he emphasizes are the *ecological* dimension of intentionality, that is, its *reciprocal* and *relativistic structure* that inseparably links organism and environment. Far from suggesting that "humans," "technologies," and the "world" come to relate after each is "given as such," the conceptual triad of "I-technology-world" suggests both *hermeneutic* and *existential* theses: (1) humans change the significance and being of technologies when their technological activities occur in worldly contexts; (2) humans change the significance and being of the world when their technological activities occur in worldly contexts; (3) technologies change the significance and being of humans when they are used in worldly contexts; (4) technologies change the significance and being of the world when humans use them in worldly contexts; (5) the world changes the significance and being of technologies when humans perform technological activities in worldly contexts; and (6) the world changes the significance and being of humans when humans perform technological activities in worldly contexts. In the account of Ihde that I am providing, the only time that "I," "technology," or "world" appear "given as such" is at the beginning of phenomenological inquiry; there, however, they appear as *clues for further analysis*—further analysis that demonstrates how the constitution of each of the relata emerges from relations to other relata. Ihde has been writing this way for a long time, and not only to clarify technological relations. This position has enabled him to demonstrate convincingly why phenomenology is not an introspective method and why neither agents nor authors have a privileged relation over their behavior or texts.

Although Verbeek and I differ on how to interpret Ihde, such divergence is, ultimately, a “family” dispute. Regardless of which of us presents the “better” interpretation, we can both agree that the postphenomenological project improves considerably upon the work of its predecessors—but that it only succeeds in doing so by conversationally engaging traditional insights and commitments. In this context, Verbeek is to be congratulated on writing a timely volume, one that will likely be influential in setting the agenda for some time to come.

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Techno-Eschatology

James Gerrie
jgerrie@uoguelph.ca
University of Guelph
Wilfrid Laurier University

Noble, David F. 1999. *The Religion of Technology: The Divinity of Man and the Spirit of Invention.* New York: Penguin Books.

It is difficult to find any fault with David F. Noble's historical scholarship. His book *The Religion of Technology: The Divinity of Man and the Spirit of Invention* is an amazing testimony to meticulous research into the metaphysical hopes of countless scientists, technologists and other intellectuals, whose musings have managed to find their way onto paper. Nobel's main thesis is that increasingly most Western people are unconscious participants in a religion of technology that strives towards the fulfillment of a "millenarian promise of restoring mankind to its original God-like perfection" (201). This of course, as Noble obliquely acknowledges at several points in the book, is an elaboration of the hypothesis, first presented by the American historian Lynn White in his classic 1967 article in *Science,* that the Judeo-Christian metaphysical outlook is the source of the Western domineering attitude toward nature. Unfortunately, a work of the sort that Noble has undertaken must rise and fall not on the accuracy of the historical evidence he amasses for the documented expression of such an attitude, but on an argument that takes into account other possible explanations the environmental crisis. This is necessary because Noble's (and White's) hypothesis for explaining the inadequately critical attitude toward technology that characterizes modern societies is not the only way of explaining the origins of this attitude.

Therefore, before assessing the contribution of Noble's book, it is necessary to have a sense of some of the alternative ways of explaining the origins of the environmental crisis and the popular belief in the inherent goodness of technology in general. Carl Mitcham and Robert Mackey in their early survey of the field of the philosophy of technology, point to three prominent types of explanation of our society's seemingly limited ability to "redirect" technology toward more environmentally responsible ends. They describe these three positions as follows:

> If [Emmanuel G.] Mesthene is right that technology is physical possibility, then a redirection of technology requires only that we choose

> to realize the new end; a "recovery of nerve" is what is essential. However, if [Nathan] Rotenstreich is right, that technology is rooted in the authoritarian mentality, then any significant change in direction of technology would involve a general alteration in man's root attitude toward the world. Whereas if [Jacques] Ellul is correct, such redirection seems out of the question, because technology develops by its own intrinsic principles. (Mitcham and Mackey 1972, 30)

Rotenstreich's position closely parallels the hypothesis presented by White that a dominant Western metaphysical outlook is the real culprit behind many contemporary social woes, such as the environmental crisis. In contrast, Ellul's position suggests that any people, regardless of their overt metaphysical beliefs, enclosed "within the technical realm" might face various kinds of restrictions on their ability to change fundamental aspects of that realm (Mitcham and Mackey 1972, 30). Mesthene's position is that it is simply a lack of moral will to do what is right, which prevents people from adequately rising to the task of addressing the challenges that technology presents.

When it comes to the explanation of the systematic failure of Western civilization to come to proper grips with its technological excesses these three positions can help us to categorize the range of positions on the origins of the environmental crisis. White's position, for example, is a popular outlook among prominent environmental philosophers, such as Arne Naess, Aldo Leopold or Albert Scweitzer. Mesthene's position has strong appeal among advocates or various forms of technology assessment and appropriate technology. However, in the field of the philosophy of technology, it is also common to find positions like that of Jacques Ellul, the common feature of which is the notion of technological dependency.

The notion of technological dependency represents any kind of theoretical hypothesis that there are features of technological practice itself that can systematically prevent critical ethical judgement of such practice to take place. In other words, technology as normally manifests itself might involve certain built-in biases that prevent proper ethical assessment of technological practices. If one believes that such biases are strong enough to prevent meaningful ethical assessment of technology and technological activities to occur at all, then one is also a supporter of a notion technological determinism. But if one believes there is some room for countervailing action, then one is simply a supporter of some specific form of dependency theory. However, there are many ways of explaining the source of dependency.

Three prominent and seminal of theories of technological dependency are those presented by Marshall McLuhan, Herbert Marcuse and Ellul. McLuhan portrays technology as being inescapably united with a form of over-stimulation or numbness brought on by habitual practice, which results in an ability of technological devices and actions to slip from conscious awareness. Marcuse portrays technology as form of bribery or vested interest that emerges from the process of technological progress, which results in a reluctance to criticize technological devices and actions. Jacques Ellul often portrays it as a form of unconscious religious zealotry. That is to say, technology, while not being an overt religion, is able to somehow galvanize the same feelings of total commitment that religions can generate in their followers. However, by its character as an unconscious faith, this kind of religion is normally beyond rational scrutiny and criticism.

Noble's position shares some affinity with Ellul's position, but it is ultimately closer to White's. Like White, he often suggests that it is simply the dominant metaphysical picture presented in the Judaic and Christian traditions of human beings being granted "sovereignty" that is the most likely source of a generally pro-technology outlook of many Western individuals. For instance, at the end of chapter devoted to surveying the gushing technological optimism of participants in the space program, Noble quotes Johannes Kepler to summarize the most common attitude of these participants: "Should the kind of Creator who brought forth nature out of nothing deprive the spirit of man, the master of Creation and the Lord's own image, of every heavenly delight?" (142). On other occasions Noble makes suggestions more akin to Ellul, such as when he also suggests that a belief in technological progress has become an unconscious religion, when he poses the question: "But can we any longer afford to abide this system of blind belief?" (208). However, there is a difficulty with Noble's argument at this point. His historical analysis actually involves an intense investigation of the metaphysical theories he feels have helped support such belief. The historical figures he examines are not "blind" believers in a religion of progress. They are conscious advocates of various metaphysical visions that emphasize the redemptive power of technological change.

If Noble is to adequately defend his claim that modern societies have generally fallen under the sway of a "popular faith" that is, for most people, subliminally indulged he will have to make a very different kind of argument than the one he presents. Rather than suggesting how such a view could have become so dominant, his book consists almost exclusively of a survey of the metaphysical views of Western intellectuals who support a belief in progress. The characteristic that they share is the belief that increasing technological mastery can somehow contribute to the "perfection" of humankind and ultimately act as "a means to salvation." There are obviously a great number of such examples in Western history.

Noble begins his story with a sustained analysis of the views of John Scotus Erigena, who he claims contributed to the overturning of a fundamentally negative view of technology of Augustine, who viewed technology as a crutch used by humankind to vainly attempt to overcome its fundamentally sinful nature. According to Noble, Erigena re-wrote Capellas' fifth century allegorical work *The Marriage of Philology and Mercury* to include the "heretofore disdained mechanical arts." According to Noble "Erigena's boldly innovative and spiritually promising reconceptualization of the arts signaled a turning point in the ideological history of technology. Some of the other major intellectual contributors to the developing religion of technology discussed in depth by Noble are Hugh of St. Victor, Joachim of Fiore, and on the protestant side of things, Francis Bacon, John Milton, John Comenius and Samuel Hartlib.

However, there is no protracted discussion of countervailing voices, or religious movements, such as the Mennonites, or theologians in the line of the Augustinian tradition of the inherent sinfulness of humankind. Instead, Noble focuses on the most millenarian aspects of the Western Religious tradition and in particular on those interpretations of the end times that focus on the image-likeness that human beings have to God as a sign of the possible perfectibility of human beings. A central claim throughout the book is that "the revivalistic mentality was sibling to the technological" (91). However, Noble does not discuss in detail how general notions of providence and hope in the future, which characterize many religious outlooks, morph into the hyper-technological optimism of his subjects, especially in the face of powerful countervailing doctrines like that of original sin. Nor does he make clear how the overt religiously dressed utopian sentiments of a select group of Western intellectuals was able to morph into a covert religion of the masses. He provides an abundance of citations of utopian/religious sentiments, but this cannot replace a specific explanation of how these various sentiments have come to supposedly dominate the ideals of large numbers of

Western individuals. Nor does he explain how such sentiments seem impervious to stark decline of overt religious observance in Western societies.

Millenarianism is not a part of all the sects of Christianity, and attitudes in Judaism about the ultimate fate of humankind are also highly contested. Although Noble provides a wealth of valuable historical information about the religious expectations of certain Western intellectuals, in the end his work can only be taken to represent a partial sampling, which cannot by itself, support the full weight of his general thesis. In general he seems to assume too great a uniformity in the religious attitudes of people in western societies. The result is that he ignores thinkers who hold more critical or ambivalent attitudes towards technology, such as Augustine, Aquinas, Albert the Great, Calvin, and Meno, as well as a host of twentieth century religious critics of technology. The result is that his argument seems one-sided and incomplete. However, the vast detail regarding pro-technological attitudes towards technological development does make an important contribution to the general argument presented by White. One can only hope that Noble has a second installment of his book in the works, in which he delves into the conflicts within the Western world.

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A Historically Grounded, Robust Anthology

Christopher Cloos
techsynthesist@comcast.net

Robert C. Scharff and Val Dusek, eds. 2003. *Philosophy of Technology: The Technological Condition—An Anthology*. Oxford: Blackwell Publishing.

From Rousseau's reply to enlightenment optimism regarding the arts and sciences, to Donna Haraway's manifesto on the benefits of cyborg politics, this anthology represents a panoramic view of the philosophy of technology. It consists of fifty-five selections that range from the historical to the progressive. The inspiration to build an all-embracing anthology arose out of, "the editors' experience as teachers of the philosophy of technology" (p. ix). Consequently, *Philosophy of Technology* is fit to serve as a primary text for a graduate seminar or an undergraduate course.

This anthology also makes an important contribution to the philosophy of technology itself. Robert Scharff and Val Dusek recognized that, "many of the current debates over technology [e.g. social constructivism vs. technological autonomy] rest upon oversimplified or outdated conceptions of science" (p.83). Such misconceptions are often perpetuated by using a 'problems-model' or 'issues-oriented' approach when framing a field of discourse. When an anthology lacks historical connectedness, it can have the unfortunate result of leading students to believe that, "philosophy mostly happens at the level of a 'debate' among a smorgasbord of competing sets of values that themselves are somehow simply found, or 'given' as logical or sociological options" (p. ix). To reduce the risk of such a liability, the anthology is organized topically and contains two areas found deficient in previous collections: 1) historical material from classical sources, 2) positivist and postpositivist conceptions of science and technology.

Philosophy of Technology is divided into six main parts. Part one, "The Historical Background," illuminates how craft-knowledge ('techné') was relegated to the status of lower understanding. Through Plato and Aristotle it becomes evident why 'technology' has been a 'late bloomer' as an area of specialization within philosophy. Then, through Bacon, Kant, Comte, Rousseau and Marx the reader is catapulted into the modern technological trajectory—an arc of development encompassed by the ideals of progress, efficiency, domination and rationality. The second division, "Philosophy, Modern Science, and Technology," highlights the influence of logical positivism upon value-neutral conceptions of technology. The readings in part three, "Defining Technology," provide the reader with four distinct characterizations of technology: a sociotechnical system of manufacture and use (Stephen Kline), an artificial extension and enhancement of human nature (Arnold Gehlen), a socially constructed system of facts and artifacts (Trevor Pinch and Wiebe Bijker) and an autonomous force (Langdon Winner). Part four, "Heidegger on Technology," begins with a reprint of Heidegger's *The Question Concerning Technology* before moving into commentary surrounding his perspective by Robert Scharff, Don Ihde, Albert Borgmann, Hubert Dreyfus and Andrew Feenberg. Part five, "Technology and Human Ends," contains three sub-sections or points of contention within philosophy of technology: *Human Beings as 'Makers' or 'Tool Users'*, *Is Technology Autonomous*, and *Technology, Ecology and the Conquest of Nature.* The final section in the anthology, "Technology as Social Practice," explores three crucial questions: what are the various permutations of the humanity-technology relationship, how does cyberspace alter our notions of self and reality and is technology coextensive with democracy?

Per the editors' indication, "We therefore welcome all criticisms and suggestions about possible sins of omission as well as commission" (p. xi), I will sketch a few suggestions.

The third section in the anthology is the shortest and weakest. It clumsily transitions from two narrow attempts at defining technology into constructivist and autonomist characterizations of technology. Lacking a rich survey of the logic and breadth of frameworks used to define technology, unlike analysis found in Ferré (1988) and Mitcham (1994), the reader is left, contrary to the editors' objections, "silent both about what counts as 'technology' in the first place and about the crucial question of the relation between technology and science" (p.83). To remedy this shortcoming, the constructivist and autonomist material in part three could be placed in a new section devoted entirely to these characterizations. Then this new section could be strengthened by adding the part five subsection, *Is Technology Autonomous*, and balanced by adding more readings from the literature on the social construction of technology. These moves would leave section three wide-open to receive high-quality writings on technology's etymology and the various ways technology has been defined and delineated.

Other important formulations of technology and science are missing from the anthology. One glaring exclusion from the section on philosophy of science is Thomas Kuhn. Similar to covering evolutionary theory by including Lamarck but not Darwin, as a substitute for Kuhn readers find Stephen Toulmin, who was a forerunner of the ‘paradigm’ notion; but it was Kuhn who popularized the term and illuminated its core components of, “symbolic generalizations, models of the underlying ontology of the field under investigation, concrete problem solutions, and the values governing theory appraisal” (McMullin 1993). This error of omission is pertinent because Albert Borgmann’s *Focal Things and Practices* and Bill Devall’s *The Deep Ecology Movement* directly rely on the ‘paradigm’ concept. Other notable omissions include Marshall McLuhan, Samuel Florman, Norbert Wiener, Friedrich Rapp, Harry Collins, Ivan Illich and Karl Popper.

Lying parallel to the need for insertion is the need for deletion. To tighten-up and strengthen this collection I recommend removing Bruno Latour’s sensationalized *News from the Trenches of Science Wars*, Stephen Kline’s question without a sufficient answer *What is Technology?*, E.F. Schumacher’s categorically misappropriated *Buddhist Economics*, Jürgen Habermas’ digressive *Technical Progress and the Social Life-World* and Andrew Ross’ philosophically butchered *Hacking Away at the Counterculture*.

Despite potential for improvement, this anthology possesses several strengths. For one, it widens the scope of the philosophy of technology. Regarding areas of specialization (AOSs), intramural inward-looking can cause cogent contributions to a field to slip by unnoticed. This collection avoids that restrictive tendency by including selections from philosophers of science, historians of economics, environmental ethicists and feminists. Regarding the last tradition, through Nancy Tuana, Sandra Harding, Carolyn Merchant and Donna Haraway readers witness the counter-balancing effects of feminist critique on a domain steeped in masculine metaphors and biases. In addition, the editors’ summaries of the readings are very accurate and concise. Commendable commissions include Rudolf Carnap, Mario Bunge, Jacques Ellul, Lewis Mumford, Hannah Arendt, Robert Heilbroner, Herbert Marcuse, Michael Heim and Emmanuel Mesthene.

In summary, this collection provides a blueprint for a new level of maturity within philosophy of technology. Synthesizing influential writings in a manner that emphasizes historical-connectedness will enable philosophers to make good on Langdon Winner’s claim that, “As studies in philosophy and technology mature...it will be increasingly important for us to think critically about the origins and relative quality of the knowledge we draw upon as we address the key questions” (p. 234). Tracing the origins of concepts and values, ferreting out inherited deficiencies and drawing on diverse range of perspectives will further the effort this anthology championed: robust philosophy of technology not limited to a 'problems-model' approach.

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Are We Running Out of Ingenuity?

James Gerrie
jgerrie@uoguelph.ca
University of Guelph
Wilfrid Laurier University

Homer-Dixon, Thomas. 2000. *The Ingenuity Gap: How Can We Solve the Problems of the Future.* New York: Alfred A. Knopf.

What happens when the resources we've come to rely on start to decline? What happens when environmental degradation begins to threaten human well-being? Can these problems lead to human conflict? When questions like these are raised in the Canadian media, Thomas Homer-Dixon is often called on to comment. Homer-Dixon is director of the Peace and Conflict Studies Programme and an associate professor in the Department of Political Science at the University of Toronto. His main area of research for the past decade has been the environmental causes of human conflict. A few years ago, after Vice President Al Gore asked him for advice on emerging conflicts, the U.S. Central Intelligence Agency even established a department to track environmental conflicts based on some of his ideas (p. 298). His most recent book *The Ingenuity Gap* has been a Canadian best-seller.

Although Homer-Dixon's major research interests have involved understanding the links between environmental and population changes and violent conflict, the main point of *The Ingenuity Gap* is to present an argument for why we should be less confident about our abilities to address such issues through the power of human ingenuity. This main argument can be broken down into two main sub-arguments. He makes a case that we can actually discern signs that our global civilization is losing the battle to preserve the environment and achieve economic and social stability. For this argument Homer-Dixon provides not only a vast array of empirical detail but also a fascinating set of personal anecdotes, many of which are drawn from his extensive travels. He also has an unparalleled knack for fashioning enlightening metaphors to describe the complex social issues he addresses. The great skill alone by which Homer-Dixon enlivens his essential scholarly endeavour makes his book well worth reading.

However, he also makes a more theoretical argument that there are inherent limits to ingenuity supply. At the core of this argument is the idea that increasing complexity can challenge our ability to come up with the "right kinds of brainpower at the right places and times" (p. 29). According to Homer-Dixon it is foolish simply to have faith in human ingenuity. As he puts it, "as human-made and natural systems we depend upon become more complex, and as our demands on them increase, the institutions and technologies we use to manage them must become more complex too, which further boosts our need for ingenuity . . . but we should not jump to the conclusion that the supply of ingenuity always increases in lockstep with our ingenuity requirement" (p. 4). He provides numerous examples of the ways that ingenuity supply can be "impeded," which range from the impact of information overload to the increasing costs of scientific advancement.

Homer-Dixon’s book makes a valuable contribution to a debate familiar to philosophers of technology, the debate between techno-optimists and techno-pessimists. However, he makes little reference to any literature from philosophy; rather, most of his sources are drawn from the disciplines of political science and economics. His main thesis, though, rests on a claim familiar to philosophers of technology, that technological development inevitably creates problems for which there may be no immediate technological solutions. As Homer-Dixon puts it, "looking back from the year 2100 we will see a period when our creations—technological, social, ecological—outstripped our understanding, and we lost control of our destiny" (p. 8).

Unfortunately, for all the skill Homer-Dixon has as a writer, there is a fundamental confusion at the core of the book. Although his arguments tend to support the techno-pessimist’s position, when it comes to drawing lessons from these arguments he seems to suggest that becoming more technologically optimistic and dynamic is the best solution to the problems facing global civilization. This conclusion seems ironic because Homer-Dixon explicitly expresses the desire to counter the views of those he calls "economic optimists" as a major inspiration for writing the book. His wish is to warn people against placing too much faith in technology. One of his chapters is even titled "Techno-hubris." In an article about the book in Canada’s national news magazine, *Maclean's*, the reviewer suggests that Homer-Dixon argues "that economic optimists, those who think that market signals and technology will guide the world safely through any future shocks, are dangerous" (Bethune 2000, p. 56). But Homer-Dixon is ultimately optimistic about the power of human ingenuity. As he speculates at the end of the introduction: "And we will think: if only—if only we'd had the ingenuity and will to choose a different course. . . . I am convinced there is still time to muster that ingenuity and will but the hour is late" (p. 8).

This final set of statements exemplifies the core confusion of the book. Is the problem one of a lack of ingenuity ("if only we'd had the ingenuity") or is the problem one of making poor choices about some forms of our ingenuity ("if only we'd had the will to choose a different course"). Or, does the problem go beyond the difficulties of finding a proper balance between these two approaches to the challenges of technology?

Homer-Dixon's conclusion wavers between the two. In some places he writes as if he would simply like people to re-think some of their technological choices—for example, when he makes the following observation:

> Moral, economic, and other values affect our choice of lifestyles, technologies, and social arrangements. Some of these things need much more ingenuity to produce and sustain than others, so our values powerfully influence how much ingenuity we need. For example, if we value things like sport utility vehicles and big houses that consume lots of natural resources, then we need more ingenuity to extract and process those resources than we would if we valued a less materially focussed lifestyle (pp. 330-331).

He is clearly aware that there is some scope for the ethical criticism of actions undertaken based on such "values." In his concluding chapter he asks "are sport-utility vehicles, five-bedroom houses, year-round air-conditioning, private summer cottages, and vacations in the Caribbean also essential elements of the good life?" (p. 398) However, instead of delving into this approach he insists throughout the book on forcing the issues he examines into the procrustean mould of the "ingenuity gap." While he presents many examples of the negative effects of certain technologies, his choice of the "gap" metaphor inevitably suggests that the central challenge facing our society is overcoming a deficit of ingenuity.

I suspect that some of the confusion is a result of a lack of awareness of a core debate that has gone on, and is still going on, in the field of the philosophy of technology. Writers in this field have for some time typically presented at least three, rather than just two, general ways of describing how our society can fail to adequately address issues like those discussed by Homer-Dixon. For example, in an early survey of the field, Carl Mitcham and Robert Mackey point to three paradigmatic positions concerning how to conceive the central ethical challenge of technology. They describe these three positions as follows:

> If [Emmanuel G.] Mesthene is right that technology is physical possibility, then a redirection of technology requires only that we choose to realise the new end; a "recovery of nerve" is what is essential. However, if [Nathan] Rotenstreich is right, that technology is rooted in the authoritarian mentality, then any significant change in direction of technology would involve a general alteration in man's root attitude toward the world. Whereas if [Jacques] Ellul is correct, such redirection seems out of the question, because technology develops by its own intrinsic principles (Mitcham and Mackey 1972, p. 30).

Mesthene's claim is essentially that technological change is a problem only because we too often fail, either through some kind of akrasia or through ignorance, to respond creatively to the new problems it presents. Rotenstreich's position represents the idea, held by many environmentalists, that a certain flawed over-arching metaphysical perspective is the source of many contemporary social woes. What they feel is most needed is a fundamental alteration in our core ethical attitudes before the problems of global civilization can be properly addressed. Ellul's position posits either some form of complete technological determinism, or some idea of dependency which imposes certain restrictions on the ability of people enclosed "within the technical realm" to be aware of and challenge aspects of that realm (Mitcham and Mackey 1972, p. 30).

Homer-Dixon's position has a great deal in common with the position of Mesthene. They share a basic assumption that one of the most important things lacking in most people's political and ethical lives is a properly focused effort to bring the negative effects of technological activity under sustained scrutiny so that creative technological problem solving can be effectively brought to bear. As Mesthene gives voice to this idea:

> "Most of the consequences of technology that are causing concern at the present time--pollution of the environment, potential damage to the ecology of the planet, occupational and social dislocations, threats to the privacy and political significance of the individual, social and

> psychological malaise--are negative externalities [that is] they are with us in large measure because it has not been anybody's explicit business to foresee and anticipate them" (Mesthene 1977, p. 163).

But such a position is hardly very different from that of the "economic optimists" who are generally too sanguine for Homer-Dixon's tastes.

Homer-Dixon is aware of the work of Langdon Winner, someone who holds a similar view to that of Ellul. He cites Winner in two places. However, Homer-Dixon seems unaware of Winner's expansive understanding of technology as "enduring frameworks of social and political action" (Winner 1986, p. x). Instead, he presents his own concept of *ingenuity*, which he defines as "sets of instructions that tell us how to arrange the constituent parts of our social and physical worlds in ways that help us achieve our goals" (p. 21). This definition, however, is not very different from Gabriel Marcel's concept of *technology.* Marcel defines technology as "a group of procedures, methodically elaborated, and consequently capable of being taught and reproduced, and when these procedures are put into operation they assure the achievement of some definite concrete purpose" (Marcel 1952, p. 82). If one puts aside Homer-Dixon's distinctive choice of terminology, his concept of *ingenuity* fits quite well with expansive understandings of technology like those of Winner and Marcel. But Homer-Dixon's choice of terminology contributes to the core confusion of the book. Because of the general positive connotations of the term *ingenuity*, his choice subtly reinforces the idea that what is most needed in most situations is to increase ingenuity supply. In other words, being critical of the idea of ingenuity is a little like being critical of the ideas of baseball, motherhood, or apple pie.

It can be somewhat disconcerting to read the work of someone from a different academic discipline who is tackling issues with which one is familiar. One must fight the sense of having heard it all before. Although Homer-Dixon re-fights many intellectual battles familiar to students of the philosophy of technology, he does so in a way that is insightful and provocative. It is important for philosophy of technology researchers to read this book because it has captured a wide public audience and will undoubtedly influence public debate concerning technological issues. Homer-Dixon's book also makes a valuable contribution to the debate between technological neutralists and those who believe that all technologies inevitably create new ethical and political dilemmas. His analysis supports the claim that the impact of technology is often ambivalent and that its negative effects are not always simply a result of malicious human intentions.

However, what one must ultimately take away from his discussion is, I think, a lesson in why it is unhelpful to cast the debate about technology in terms of the binary opposites of "economic optimist" and "environmental pessimist." By accepting this opposition Homer-Dixon ends up falling into the trap of feeling that he ultimately must choose sides. In this overly limited view of the nature of the ethical and social challenge of technology, his work demonstrates the importance of including in one's analysis some awareness of the third type of paradigmatic position which Mitcham and Mackey attribute to Ellul. Homer-Dixon is aware that there are two fundamentally opposite ways to address the problems that our technological choices create. As he describes these two possibilities, "solutions to an ingenuity gap can involve either reducing the requirement for ingenuity or increasing its supply (or both)" (p. 397). It is clear that for Homer-Dixon the former typically involves the ethical criticism of problematic technologies, whereas the latter typically involves the creation of new technologies to address the problems created by problematic technologies. But as he admits, "for some reason we tend to think first—and sometimes almost exclusively—about increasing supply" (p. 397).

In this final observation Homer-Dixon identifies what I think is one of the most interesting questions concerning technology. It is unfortunate that it only comes at the end of his book. Ellul and others holding similar views, such as Winner, might be right in suggesting that we can become subject to some kind of deeply embedded bias towards the approach of increasing ingenuity supply. Homer-Dixon is aware of this kind of bias, but does not consider it to any great length, and, at least partially, even seems to succumb to it. One gets the impression that what he really wanted to do was question this kind of bias, but that he felt such a view would inevitably be so marginalized that it was imprudent to pursue such an approach to his subject matter. As he admits in an interview with *Maclean's*: "I'm fed up with being labelled a doomsayer; what separates me from being one of them is that I'm pretty impressed with human beings, their creativity and adaptability" (Bethune 2000, p. 56). In this desire to put distance between himself and the "environmental pessimists," Homer-Dixon attempts to strike what he feels is a proper balance between emphasizing the need for human creativity and the need for the ethical criticism of the products of human creativity. But in the absence of an analysis of his observation about technological bias, his position comes off sounding like an endorsement of the position of Mesthene over that of Rotenstreich. I cannot help but feel his work would have benefited greatly from a deeper examination of the work of the likes of Winner and Ellul.

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Hacking: The Performance of Technology?

Cathy Legg
Cycorp, University of Melbourne

Thomas, Douglas. 2002. *Hacker Culture.* Minneapolis: University of Minnesota Press.

The word "hacker" has an interesting double-meaning: one vastly more widespread connotation of technological mischief, even criminality, and an original meaning amongst the tech-savvy as a term of highest approbation. Both meanings, however, share the idea that hackers possess a superior ability to manipulate technology according to their will (and, as with God, this superior ability to exercise will is a source of both mystifying admiration and fear). This book mainly concerns itself with the former meaning. To Thomas this simultaneously mystified and vilified, elusive set of individuals exemplifies "the performance of technology" (*xx*), showing the way in which "the cultural, social and political history of the computer...is fraught with complexity and contradictions" (*ix*). In fact, he claims that hacking is more a cultural than a technological phenomenon, citing Heidegger's, "[t]he essence of technology is not anything technological" (56).

In part one of the book, "The Evolution of The Hacker," Thomas claims *secrecy* to be the defining issue of "hacker culture." Society has an ambivalent, contradictory relationship to secrecy, which the pranks of hackers highlight in paradoxical and/or 'supplementary' ways. For instance, "[s]ecrets can preserve an institution's identity, but...they can also prevent a hacker from being identified" (*xi*). Hackers play with these contradictions (the hacker "both deploys and disturbs the notion of the secret" (189)). Thomas seeks a "genealogy of secrecy" in the Foucauldian sense.

To this end, Thomas retells much of hacking's history, from its little-known origins in phone "phreaking," through the hacker Eden of the 1960s. During this period (still fondly remembered by many participants) in the computer labs of MIT, Cornell and Harvard information and equipment were shared and it was accepted that any person had the right to tinker with anything that they could improve (such that, "[i]n a perfect hacker world...anyone pissed off enough to open up a control box near a traffic light and take it apart to make it work better should be perfectly welcome to..." (15)). Thomas notes the irony, however, that much of the funding for these wonderfully free and creative communities derived from the military. The 1970s saw the birth of proprietary software and the beginning of the end of hackers' freely sharing files, tools and information, all of which corporations began to assert ownership of. This moment is perhaps epitomized in Bill Gates' famed cease-and-desist "Open Letter To Hobbyists" regarding sharing of his Altair BASIC. Thomas suggests that the "old school" of hackers capitulated to much of this enclosure of the hacking commons, causing the next hacker generation to mix anger with admiration for them. (Not all of the old school *did* capitulate however; a notable exception is Richard Stallman's Free Software Foundation and its unique "copyleft" license, a discussion of which would have complicated Thomas' argument.)

Thomas credits two events with causing the concept of the hacker to jump into popular consciousness: the evocative 1983 movie "War Games," and the misguided release in 1988 by a college student of the infamously damaging Internet Worm. A major crackdown by law enforcement agencies followed in the early 1990s, which led to a certain politicization of the hacker community. Thomas finishes by sketching some of today's issues, such as the split in the hacker community between so-called "white hats" (who protect systems and – allegedly – hack only with consent) and "black hats" (who do not).

As well as hacker history, Thomas explores hacker "language-games." Hackers famously play with spelling and the ASCII character set, writing words such as "3133+" ("elite"). This phenomenon bears a curious similarity with certain postmodernists' notorious semiotic play. Thomas draws materiality of the sign conclusions from this, arguing that hackers' letter-replacements are "not merely substitutions but translations," which remind one "first and foremost, that writing itself is a kind of technology" (57). A somewhat formulaic nod to Plato's *Phaedrus* follows (58).

In part two, "Hacking Representation," Thomas examines literature produced by hackers themselves, the way they are represented by non-hackers, and the complex interplay between the two. (For instance, hackers are "prone to precisely the same kind of overstatement and mischaracterization of their activities that the media and government officials are" (117)). Hackers are revealed in this section as superb wielders of irony. Firstly, the editors of the underground magazine *Phrack*, aware that their publication was assiduously studied by law-enforcement agencies and corporations, formally copyrighted their work, stating that it was available free of charge to "the amateur computer hobbyist," but that any "corporate, government, legal or otherwise commercial usage" was forbidden without "prior registration," at a fee of $100. Though many wrote in saying that they were planning to pay, "but don't tell anyone," only one person ever did, which the editors delightedly sermonized about in the magazine. Thomas's analysis of this act is somewhat utilitarian. ("If *phrack* was to be watched or monitored, this agreement was designed to make sure that those who ran *phrack* could monitor the monitors" (129). Editor Chris Goggan's own words, however, speak more of an intrinsically glorious act ("I named several people who were not only getting the magazine but in one case, they were spreading it around and, of course, none of them even contacted me for registration. I had a riot with it. It was a lot of fun" (128-9)).

Secondly, when the Hollywood movie "Hackers" (widely scorned by the genuine article) appeared, some hackers defaced the "Hackers" website. The following new text appeared:

> Hackers, the new action adventure movie from those idiots in Hollywood, takes you inside a world where there's no plot or creative thought...When a seriously righteous hacker uncovers MGM's plot to steal millions of dollars, Dade and his fellow "throwbacks of thespianism"...must face off against hordes of hackers, call in the FBI, and ponder a sinister UNIX patch called a "Trojan." Before it's over, Dade discovers his agent isn't taking his calls any more, becomes the victim of a conspiracy and falls into debt. All with the aid of his VISA card. Want the number? (167).

Again, Thomas's analysis of this hilarious piece of play is rather 'straight':

> There are two basic points of critique in this Web page hack. First, the hackers assert that the film is in some way unrepresentative of hacker culture...A second critique has to do with the very premise of the film. Those who hacked the web page argue that MGM...cannot make a film about hackers and global capitalism without implicating itself (167-8).

In Part Three, "Hacking Law," Thomas explores "the juridical construction of the hacker." The issue of the *punishment* of hackers, and its relationship to technology, is obvious grist to his Foucauldian mill. He notes "[t]he highly sexualized metaphors of penetration and ravaging (177)" often used to describe hackers' activity. Also, hackers would seem to trespass in the systems they penetrate, but in what sense? Despite the fact that they are not physically present in, say, the Pentagon's mailserver, and even their virtual presence takes the form of a feigned on-line persona with a different name, "it is the hacker's body that must be found, identified and ultimately prosecuted" (185).

In this regard, Thomas tells the story of the hunt for the body of Kevin Mitnick, who was tracked down and arrested in 1995. Thomas notes how much the press focused on Mitnick's body. It was noted over and over that he had a weight problem. He was unilaterally diagnosed as having "an addiction" which led him to hack and he was ordered to attend 12-step meetings (192). His body was also legally severed from all contact with computers, Sony Walkmans, and even telephones (which led to him being put in solitary confinement for 8 months in an earlier jail sentence). Thomas suggests that much of the fierceness of such penalties arises from hackers' being "made to stand in for an issue of great cultural anxiety" (216), i.e. the increasing role of technology and attendant surveillance in everyone's life. This last section is possibly the most interesting of the book. Thomas seems to have thought deeply about the issues concerned. Also it is just a great (*albeit* tragic) story.

Much of the history and life of hackers recounted in this book has been told already (see, for instance, Bruce Sterling, *The Hacker Crackdown*). However to take a postmodernist perspective on the phenomenon is novel and Thomas' treatment of many issues is very suggestive. Much of hackers' irony and intervention does indeed seem to embody a 'supplementary' logic not capturable by a purely analytic perspective. Ironically, however, Thomas himself in his presentation of "hacker culture" is relentlessly discursive. How would hackers themselves respond to this deployment of postmodernist theory? Is it possible that they might 'hack' it? The hacker spirit is curious in that despite being so apparently irresponsible, it is also robustly practical. Hackers accord respect to those who can manipulate technology according to their will, and gain the power that comes from that. They are quick to lampoon just about anything else. Thomas has done his homework, but the fact that he is not a programmer is evident in remarks such as, "Certain software is written to handle information in terms of a 'buffer.'" (105). Whether there might be some perspective that could embrace postmodernist insights with respect to the logic of irony and intervention, and hackers' unparalleled understanding of how to actually do things with technology – and what might be able to be 'hacked' by someone who possessed such a perspective – is an interesting question.