# Harnessing Our Very Life

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**Abstract** The Aristotelian ideas of nature (*physis*) and technology (*techné*) are taken as a starting point for understanding what it would mean for technology to be truly living. Heidegger's critique of the conflation of scientific and technological thinking in the current era is accepted as demonstrating that humanity does not have a deep enough appreciation of the nature of life to harness its essence safely. Could the vision of harnessing life be realized, which we strongly doubt, living technology would give selected humans transforming powers that could be expected to exacerbate, rather than solve, current global problems. The source of human purposefulness, and hence of both technology and ethics, is identified in nature's emergent capability to instantiate informational representations in material forms. Ethics that are properly grounded in an appreciation of *intrinsic value*, especially that of life, demand that proposals to give humanity the capabilities of living technology address the social, political, economic, and environmental problems inherent in its development and potential deployment. Before any development is embarked on, steps must be taken to avoid living technology, whatever the term eventually designates, becoming available for destructive or antisocial purposes such as those that might devastate humanity or irrevocably damage the natural world.

**Keywords**
Living technology, teleology, Heidegger, intrinsic value, ethics, Prometheus

## 1 Introduction

Living technology has been broadly defined as technology whose utility is derived from the fundamental properties that it shares with living systems, including self-assembly, self-organization, metabolism, growth and division, purposeful action, adaptive complexity, evolution, and intelligence. A broad range of examples taken from the diverse fields of artificial life software, reconfigurable and evolvable hardware, autonomously self-reproducing robots, chemical protocells, and hybrid electronic-chemical systems has been used to illustrate the power of technology based on the core features of life [3]. Some examples—protocells, moving oil droplets, electronic chemical cells—have been judged to be systems on the verge of making the transition to life, although it is

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acknowledged that any such technology is in its infancy. On the other hand, consideration of a set of characteristics universally associated with actual living things leads to the conclusion that some existing technologies are already "very much alive"—but living technology has yet to show its full potential, with significant leaps to more mature forms expected to happen rapidly [3].

Proponents of living technology portray it as full of promise. It will produce advanced materials that can sustain and repair themselves, yield solutions to energy and atmospheric problems, and even allow exploitation of extraterrestrial environments. It is said that these possibilities place humanity on the verge of the most transformative evolution of technology that current generations will experience. And therewith comes a burden of responsibility. In response to that burden, considerable effort has been expended on analyses aimed at identifying, in advance, ethical questions that are likely to arise, the specific character of such questions, and waypoints marking their advent, in the development of living technology [4, 5].

In this contribution, it is our purpose to conduct a searching critique of the idea of living technology and to investigate difficulties posed by the idea within a nexus of scientific, philosophical, and ethical problems where uncertainty concerning human identity is currently stretched to the limits. What we have to say will be inescapably political, just as the enterprise that goes under the name of living technology is itself. For that reason we will attempt to make our assumptions absolutely clear so that further debate does not founder on ambiguity, confusion, and implicit contextual matters. Our position is that limited scientific conceptions of life's fundamental characteristics currently provide a very poor foundation for their technological exploitation and that premature activity in some fields of technological endeavor will channel humanity into creating a future that is worse than many others that could still be realized.

Our position rests on the premise that living things have an intrinsic worth, and it is from this assumption that we seek the development of ethical principles that are neither limited by the perspective of scientific knowledge nor inconsistent with it. We are critical of political and institutional systems and processes that perpetrate a global measure of worth dominated by the economic rather than the biological dimension. We maintain that the practice of science is sinking into a commercial mire and that even for the sake of knowledge itself it is necessary for scientists to display much broader responsibility for their use of economic resources and the consequences of their collective activities. Although we commend the efforts of the various institutions, groups, and individual authors who have initiated and undertaken pertinent ethical enquiries concerning the technological exploitation of life's basic processes, we issue the challenge to contemplate a more penetrating analysis of the historical context in which the idea of living technology arises and the relationships of power through which it is maintained.

Whether or not the terms *living* and *technology* can be given clear scientific definitions, *living technology* has been mooted as something that falls within the ambit of scientific enquiry, linking essential features of biological systems to their potential exploitation in systems that are purpose-built by humans. The novelty of the idea is that systems constructed by humans might be considered to be just as alive as any organism whose life is a legacy that can be traced through billions of years of evolution to the origin of everything biological. The clearest example of truly living technology would be a useful, self-sustaining, reproducing, microbiological-type system that had been put together from laboratory chemicals. As will become evident, we adopt stringent criteria in determining what can truly be considered to be living. We do not consider it sensible to view life as a special property, or set of properties, ascribable to some material systems. That would be like describing energy as a property ascribable to various entities in the cosmos, rather than the primordial matter, *Urstoff*, of which everything material is originally composed.

The ideas of living technology and artificial life clearly overlap, but in living technology the emphasis is on the application of lifelike characteristics to the solution of problems. These range from the nanoscopic manipulation of materials to planetary sustainability. The individual terms *living* and *technology* are brought together with the intent of describing new, rather than existing, possibilities. This synthesis of life and current human aspirations is considered to be imminent, with the implicit assumption that it should not be a matter of ethical concern per se, at least not on the scale envisaged in the myth of Prometheus [50]. The main ethical concerns expressed so far have centered on the way individual problems should be anticipated and addressed as they arise, especially to ensure the health and safety of human society and the general biological environment.

Our approach will be different. We will invert the normal procedure of carefully defining the substantive character of the context in which ethical concerns potentially arise and then evaluating evident problems within some stated framework. Rather, we will outline elements of a general framework of thought about biology, technology, and ethics within which the relationship between human aspirations and the underlying realities of biology take on an ethical aspect that has been generally neglected, and often ignored or denied, within the scientific community. Our justification for pursuing the inquiry in this way is that the proposal to create living technology strikes at the heart of the relationship between humanity and nature—indeed, at what we take each to be.

Every change in scientific knowledge and know-how influences, perforce, how we conceive of nature, humanity, and the value we assign to them; and often in ways that can only be understood and evaluated with considerable hindsight. However, the very uncertainty that characterizes perception of our current situation and how it should be interpreted points to the inescapably ethical dimension of humanity's technological engagement with the world. An authentic enquiry into the ethics of new technology must search far and wide among the interstices of the questions "Who are we?" and "By what right?" This article aspires to survey the idea of living technology within the territory of these questions.

## 2 Nature and Technology

Recorded thinking about the character of what we now call technology dates back, in the Western tradition, to the pre-Socratic Greek philosophers, but most of what is known of such thinking comes to us through Aristotle. The loose translations of the Greek words *physis* as "nature" and *techné* as "technology," especially as used in Aristotle's *Physics B 1*, cannot do justice to his worldview and that of his predecessors. However, discussion of these translations does serve as a starting point for understanding the historical transformations that have taken place as a result of advances in scientific knowledge and the progressive subjugation of natural processes to human control during the modern era [17, 19]. The most important transition in Western thinking was that from the Aristotelian conception of nature as purposeful to that of the Cartesian conception of nature as mechanical. During the more than three and a half centuries that have passed since this transition began, facilitated by Darwin's evolutionary biology and the consequent rise of Freudian and experimental psychology, the idea of teleology or purpose in nature has been all but completely stripped of scientific respectability, in favor of a view that causes of a material, mechanical kind are sufficient to explain all the workings of nature.

While there is no reason to abandon the universality of physicochemical laws that determine how all change in the material world takes place, there is reason to question the interpretation of such laws as providing a complete scientific description of everything natural, especially biological phenomena [7, 8, 24]. In fact, it is reasonable to interpret much of Aristotle's *Physics* as a treatise on biology, especially as he concerns himself with "final causes" or teleology. For Aristotle, motion that we now regard as mechanical was just one sort of change in the world, all of which was to be interpreted teleologically. Even if he was mistaken in applying this basic notion to kinds of change in which there is no purpose that is directly manifest to science, we contend that modern science is equally mistaken in claiming that the universal application of mechanical laws to physical phenomena ipso facto excludes from nature the possibility of teleology. Authors like Dawkins [42], Weinberg [40], and Atkins [2] share the fallacy that the methodological materialism of physics and chemistry, in itself uncontentious, can now be read back out of science as a conclusion confirming, by scientific method, that the whole of nature is necessarily purposeless.

To define technology, at least as it is usually understood, requires recourse to some idea, perhaps only implicit, of intention, goal-directedness, or purposefulness, that is, of teleology. It is only when technology is so defined that it becomes possible to distinguish its products from things of purely natural origin. It is the taking of something from nature and applying it, using it for some purpose, that defines a realm of technology, even when the activity is that of members of species other than *Homo sapiens* [43]. And it is the relation of utility between parts of biological systems, as between an enzyme and a cell's requirement for a metabolite in relation to its maintenance and survival, that marks them as intrinsically teleological. Aristotle is now considered to have erred in implying that the explanation of any movement, for example, that of molecules in a gas at equilibrium, requires recourse to teleology. However, this does not detract from his monumental attempt to describe in the most integrated and universally applicable manner the generative capacity of *physis*. In fact, by elucidating the point at which Aristotle was mistaken it will perhaps be possible to rehabilitate teleology within science, as writers as diverse as Klapwijk [26], Broom [8], and Alexander [1] are concerned to do. We may then come to a better understanding of how technology and biology stand in relation to one another.

Recognition of the similarity between nature and technology led Aristotle to deviate from the pre-Socratic conception of *physis* as "being" the fundament of existence, and to set up an explanation of nature in terms of a "metaphysics of production": nature understood in analogy to *techné*, knowledge of how to produce artifacts. When the *physis* of the pre-Socratics is transformed by Aristotle so that it becomes understood analogically as a process of production, nature becomes that which produces itself; nature is a self-making system, and thus everything in nature is conceived as being brought into existence by moving toward its own end. Although natural things and artifacts move from potentiality to actuality in different ways, Aristotle's *physis* and *techné* each represent an ultimate source (*arché*) of things that exist. In both cases the source is identical with the final cause (*telos*) of what is produced, but the difference lies in the character of the ends, the purpose. In the case of *physis*, the *telos* is nature itself and the impulse is internal, whereas in the case of *techné* the origin and end coincide and lie outside of that produced by *techné*—lying instead in the prior conception (*eidos*) of how the thing appears to the producing agent. In *techné* the appearance of a thing precedes, in its conception, the generation (*genesis*) of the thing; whereas in nature the thing itself embodies its *own* end, and matter and form are inseparable. Matter has natural forms that are realized without the action of an agent. Therefore, the primary relationship of matter and form is to be found in *physis* as opposed to artifacts; and what is natural is thereby distinguishable from what is artificial.

It could be argued that this distinction is broken by organisms, because they are products of nature but also carry genes, which function as a preexisting design (*eidos*) for their generation. We do not accept this argument, on the grounds that the genes of an organism can be said to be a representation of it, or a design for its generation, only on account of the prior existence of cells, belonging to that broad type of organism, which serve as an interpreter of appropriate genetic information [49, 51]. The genetic design of an organism (the genotype) does not precede the existence of cells from that type of organism (the phenotype). This brings into focus how our provisional definition of an important prerequisite for life differs from other proposed definitions. The genes and the cell type, the unity of genetic information and its generative interpreter, are what constitute the living entity, not some specification of the organism's spatiotemporal composition. Indeed, we take the spatiotemporal coupling of information and its interpretation to be the foundation of all known biological phenomena. This places a strong demand on any claim that something is a form of artificial life—it should instantiate a completely new design for such a coupling: an artificial, technologically produced coincidence of origin and end (*telos*), not something copied from what nature has provided as an example of life on this planet.

For neither Aristotle nor most of his predecessors could nature be characterized in terms of the properties and behavior of an underlying, unchanging substance that simply changes its form. Rather, nature is a special kind of "movedness": something responsible for generating and changing things from within. Unlike artifacts, natural things attain their form without any prior conception, and their coming to being, their taking form, their appearing, their emergence, constitutes nature itself as *genesis*. As already indicated, this conception of nature as generation did not give Aristotle easy access to the modern understanding of the locomotion of objects as simple spatial translation.

In analogy to the generation of artifacts, Aristotle sought to explain locomotion in terms of some internal, natural *telos*—the striving of things to come to rest in their natural place, governed by their material composition: Things finally come to be, are naturally generated, in purposeful fulfilment of the movement from potentiality to actuality. More than any other part of Aristotle's science, it was this teleological way of thinking about movement, even the simple locomotion of an object, which was abandoned in the transition to the Newtonian worldview. Mathematical descriptions of the spatiotemporal disposition of material objects can be formulated without reference to intentionality.

In agreement with Heidegger [19], we would argue that the modern scientific attitude to nature and technology is determined by an Aristotelian "metaphysics of production" but one that has been completely stripped of its underlying teleology [17]. Modern science has become conflated with technology, even epistemologically, so that much scientific knowledge refers to a domain of events that occur within, or as a result of, machines, rather than something that is uncovered as happening outside of human intervention in nature. Modern physics confronts nature with exceedingly complex machines to produce outcomes, even forms of matter that would otherwise never exist, but more generally, phenomena produced in highly constrained experimental situations. A similar situation exists in biology. Organisms are manipulated to produce novel species that could not conceivably arise through any coincidence of undirected natural events—all this as a way of uncovering the "nature" of biological systems as they are given to us by evolution.

Forman [13] has investigated historical and sociological aspects of the merging of science and technology. He describes how science, as disinterested inquiry, has been downgraded and technology, as innovative enterprise, upgraded in cultural rank over the last three decades or so, the same period during which the basic properties and functions of living systems have started to become objects of human exploitation. Molecular genetics and the endeavors it has spawned (artificial life, synthetic biology, and living technology) are now examples of largely technological rather than scientific enterprise, with strong links to the privileged economic base of global human power [31]. That is not to say that these endeavors cannot fulfill purely scientific aims—rather that the forces driving them have more to do with technological achievement than with integrated theories of how natural processes occur without purposeful human manipulation or interference.

New modes of biotechnological production define the way in which biological phenomena, even entities, are described: For example, some transgenic crop varieties are named according to the numbering of the "event" of their creation. The behavior of new organisms produced by molecular biologists is studied with at least as much interest as the behavior of organisms originally found in nature, and knowledge of *what happens* in organisms, or to them, is conflated with *what can be done* with them, to the extent that molecular biology, a realm of knowledge, and genetic engineering, a form of biotechnology, have become virtually indistinguishable. Heidegger [21] goes so far as to say that in modern science the distinction between Aristotle's *physis* and *techné* has been completely collapsed and the essence of science now lies in the essence of technology—an instrumental thinking (*Gestell*) that constrains, orders, and divides nature into predetermined compartments, exposing all its features as a stockpiled resource (*Bestand*), ready for human use. (See also [20].)

## 3 Heideggerian Critique

What if Aristotle, taking him to be the main representative of a long intellectual epoch, had effected a description of simple locomotion through consideration of mechanical causes, as was completed by Descartes and Newton, and left teleology to those biological phenomena in which the operation of representations and relationships of utility, the hallmarks of purposefulness, are evident? Then we might have inherited an attitude to nature that was better suited to understanding the complex constellations of molecular causes that we find associated with even the most elementary biological phenomena. Of course, Aristotelian thought is not composed of exchangeable modules, and the historical development of Western thought is not to be undone, but there is value in grasping what preceded Aristotle's "metaphysics of production" in the thinking of pre-Socratic philosophers [20].

In this older conception, *physis* is not that which produces itself, but that which comes into being of its own accord; and its study falls into a division of knowledge (*theoria*) that is distinct from *techné*, the knowledge of how to make things. *Physis* is the fundament of existence, it is the essence of what is natural, and it is teleological: Things move from potentiality to actuality toward their own intrinsically defined ends and so emerge into the world. *Physis* is first characterized by its generative power, not its mechanical processes.

In spite of his eulogizing this worldview that he sees shining through the scant surviving literature of pre-Socratic times, Heidegger repeatedly opines the impossibility of recreating it. However, there is something essential in the ancient relationship, between *physis* and *techné*, which enlightens the modern view of nature and technology. Heidegger characterizes the original ground for technology—the building of boats, weapons, and houses—not primarily in the seemingly obvious purposes of transportation and the procuring of food and shelter, but as an aspect of humans binding themselves to experience of the essence of nature. This interpretation of human living as "dwelling in nature" is attested to by features held in common by early human cultures and many extant indigenous cultures: the representation of natural forces as divinities and the rituals prescribed for engagement with them. Totemic representations inextricably tie the arts of production to the celebration of the ways of nature. Even the simplest tool has a value beyond its utility relative to human purposes.

Heidegger links this view of "dwelling in nature" as the ground of technology, in a seeming paradox, to his view that technology does violence to nature by taking it under control and constraining its operation to humanly conceived outcomes. And that is how humanity encounters its own place in nature, because its control is always temporary: the overwhelming force of nature eventually rends all human construction asunder, and it disappears into the mists of nature's own history. Nature's pushing back reveals to us the finitude of our humanity, our place in the universe that affords us the temporary opportunity to create something that belongs to us, but never to become masters of the cosmos [38].

However, the modern technological attitude does not bring humanity into this sort of primordial temporal experience of nature [21]. Rather than bringing nature to light, modern technology tries to change nature, and it cuts human consciousness off from experiencing its essence. The origin of this modern technological attitude can, to a large extent, be traced back to when Plato's unmoving *eidos* (archetype) replaced the emergent power of *physis*, "movedness" as the perceived ground of existence, whereafter *techné* becomes a mode of planning to do and make things, to produce outcomes. The ultimate outcome is technology that is no longer under human control, and humanity is found taking even itself as a resource for the accomplishment of every possible purpose. Because nature is construed as the realm where everything is subject to the absolute necessity of inviolable law [11, 27, 36, 42], no purpose has any meaning that is rooted in nature.

The only hope of mitigating the consummate nihilism to which this thinking leads is for humanity to become cognizant of the extreme danger of violent destruction it faces, not necessarily conceived physically, at the behest of overwhelming, unchangeable natural force. We have as yet no conception of the character of the constraints nature places on what is technologically achievable when all of our humanity, including our biological and emotional constitution, is used as resource, but we have surely embarked on the path of commodifying and manipulating even these fundamental aspects of ourselves with special tools created for those very purposes. Therein lies danger, and according to Heidegger only "releasement" (*Gelassenheit*), detachment, passivity, and self-composure, to be achieved through meditative as opposed to manipulative modes of thinking, will bring us back to an appreciation of the underlying natural character of what we are bringing into being. The hubris of modern technology is no match for nature [38], so what will become of humanity? Will living technology help us?

In a novel interpretation and critique of Heidegger (esp. [21]), Riis [32] suggests that the modern convergence of technology and life is rooted in the ancient Greek conception of technology as a way of bringing forth (*poiêsis*) that strives to emulate the ideal of nature (*physis*). In this view, living technology will be a kind of technology that has ceased to be technology because it is able to reproduce itself naturally without the aid of a craftsman. It is the end of technology. The craftsmen of living technology will do no more than steer the initial unfolding process so that nature and technology eventually merge as they move toward a fusion in which the craftsmen become obsolete. According to Riis [32], the ancient conception of nature as "the mighty, omnipotent and unstoppable force that constantly unfolds itself and creates new beings, only to decompose them and let them revive in an endless oscillation" entails the same danger that Heidegger [21] ascribes to the essence of modern technology: our mindset of *Gestell*, which "strives to appropriate all domains of being only to sap their energy in order to sap more energy from other beings indefinitely"—a nihilistic force that has no meaning except from keeping itself in motion.

Riis [32] sees living technology as possibly "leading the way to a new kind of technology, which does not necessarily exploit nature, but has the capacity of bringing-forth in a way that supports and re-vitalises nature." We detect in current projections of its development an element of Manifest Destiny determinism, the hope of an imminent, better future in which humans lightly regulate the cooperative productive efforts of a benign nature-technology synthesis that has superseded them. We do not share this vision, not for philosophical reasons, but for reasons of experience of the power structures that currently hold sway in our global society. It is in this context that we see danger in attempting to produce technology that can truly be said to be living. The danger lies in the power it can deliver to agencies, whether individual or collective, to own, manipulate and control to an unprecedented degree, and to the exclusion of others, aspects of nature that have until now been outside the range of human exploitation.

## 4 Living Technology

For technology to qualify as living, it has been suggested that it should be "robust, autonomous, self-repairing, self-reproducing, evolving, adapting, and learning—a powerful combination of life's core properties" again listed as "including such properties as the ability to maintain and repair itself, to autonomously act in its own interests, to reproduce, and to evolve adaptively on its own" and further in terms of "lifelike qualities: growing and repairing . . . reproducing, adapting to changing circumstances, evolving creatively" [3]. Such lists of features have not been intended to negate the possibility of a clearly stated definition of the terms "life" or "living" but they have been deemed adequate for the demarcation of living technology. However, in order to uncover the deep connection between what is living and what is technological, it is necessary to define more clearly what may legitimately be called "living." Almost everything said to be living can also be construed as bearing a close relationship to technology, by virtue of the utility and apparent purposefulness that one part of a living system bears to other parts. A reasonable separation of the living from the technological can then be achieved by limiting the meaning of the word "technology" so that it refers to the involvement of artifacts in apparently purposeful human activity. Living technology can then be differentiated into a primary variety, in which the technological artifact itself is alive, but not on account of descent from any biological system; and a secondary variety, in which an existing natural biological system is harnessed as a technological artifact, or part thereof.

In attempting to better understand the relationship between technology and biology, we are driven back to inquire into the conditions under which human purposefulness has emerged as part of the natural world. The emergence of the human ability to create representations of future outcomes and reflect on them required the prior occurrence of the much earlier emergence of the living from the nonliving. The features of the natural world that made that first transition possible are now to be harnessed as means to human ends in living technology. It is impossible to describe what living technology will harness without admitting of nature that it is most profoundly characterized, not by the partial order to be found in the mechanics of picoscopic or yoctoscopic events in the material world, but by its potential to bring forth systems that create their own self-representations—first, genomic code-scripts [49], and ultimately, what is loosely called "consciousness" for lack of any better way of alluding to the reflexive experience of subjectivity. When this aspect of the natural universe, of which we are a part, is taken to be as important as its material aspects in determining its continuing unfolding, then the idea of living technology indeed becomes a burning question concerning our responsibility toward ourselves, our future, and the world at large. Could living technology herald the emergence of a radically new type of phenomena of completely unforeseeable novelty from within human culture, analogous perhaps to the emergence of spoken and written human language?

The proponents of living technology and synthetic biology see their fields as having such Promethean proportions [50]. Gibson et al. [16] created a completely synthetic genome for a cell and additionally encrypted in the DNA sequence a quotation from the biography of Robert Oppenheimer, *American Prometheus* [6]; Bedau et al. [3] predict "a truly singular event in human history" driven by artificial systems that acquire "a powerful combination of life's core properties that no current technology yet embodies." However, the tragedy entailed in the myth of Prometheus, portrayed more recently in *Frankenstein* [35], and the interpretation of the tragic element of the myth in terms of nature's reaction to human endeavor [20, 21, 38], has not been discussed as a matter of great concern in relation to the ethics of living technology, except implicitly by Riis [32]. Could it be, as the myth suggests, that the historical transition envisaged by proponents of living technology—artificial life and synthetic biology—will play out as the encounter of *H. sapiens* with some aspect of reality of which, so far at least, we have only the faintest inkling: the "life" that we cannot yet adequately define, but that is, in ways we have not yet measured, as fixed and immovable in its reactive behavior as the physical aspect of reality? There is now a growing suspicion that the answer may be "yes" as is most evident in very recent concerns about sustainability, and that much current human behavior is an affront to norms whose emergence preceded our evolutionary arrival in the cosmos [50]. We believe that using, for finite human purposes and within the context of current understanding, scientific representations of the mechanisms that have enabled the emergence of biological complexity, carries with it the threat, or *danger* [21], of doing irreversible damage to both the natural world and humanity, through the unrestricted technological application of scientific knowledge. There is tragic irony in the potential for knowledge to lead to the destruction of the source from which it is derived [38].

The idea of technological creations being able effectively to reduce humanity to some subsidiary functional role, supporting the existence of its mechanical masters, is not new. A century and a half ago Butler [10] considered the role of machines in human society and the extent to which they could evolve as a result of the "natural selection" of human decisions. He had a prescient understanding of the role of information transmission in the processes of inheritance, viewing evolution as dependent on much more than material continuity from one generation to another. Although we would now reject his mentalistic conception of how genetic memory functions [15], he argued satirically that the technology of his period was already coming to life. Understood within the context of his time, Butler's conception of living technology was not very far removed from the modern conception, except that he made light of the idea, suggesting that if technology really could come to life then all machines should be destroyed to save humanity.

## 5 The SPLiT Proposal

By way of example, let us consider what has been proposed as a flagship of living technology—*sustainable personal living technology* (SPLiT). Over 100 scientists have put their names to a proposal to build and deploy a global system of machines in order "to bring ICT [information and communication technology] to life with novel adaptive manufacturing for a creative society by developing the Personal Fabricator Network (PFN)." According to the declaration of the initiative [29], society needs this technology, which "will remake the manufacturing profile of the world, with Europe returning to its former leading position." The proposal has been put forward in answer to a "call" under the European Union's Future Emerging Technologies Program. Thus, Butler's dystopian vision is replaced by a utopian one [29]:

> By enabling individual digital manufacturing and deployment in an informed self-organizing social framework, the PFN will enable novel (genetic) description language. Such a universal

production language will form the core architecture of the PFN that will render its technology communicable, flexible, adaptive, and evolvable; making it both sustainable and appealing to live with, just as evolution and life are intimately connected.

There is an almost subversive, Gandhian element implied in the vision. Were it to succeed, a global network of individuals in possession of personal fabrication machines might cooperate to squeeze the now powerful centralized industrial manufacturers out of the global economy. The difference between this outcome and what various political entities like Attac and the Occupy movement seek to achieve [25] is that it would happen automatically, as a property of the technology so to say, not as the result of any directly applied intent or effort to address economic or political injustices. The SPLiT vision also includes the idea of ecologically sound means of recycling material developing spontaneously, simply as a result of the mode and locality of material use, rather than out of any direct concern for the environment. The desirable outcomes are envisaged as self-organized products of the living technology.

We wish to make several criticisms of this vision. The first is that we do not accept the designation "living" as it is being applied to sophisticated, adaptable, small-scale manufacturing systems whose programming is linked through human social networks. The proposed architecture lacks what we view as the essence of natural living systems: The existence of a self-maintaining, autonomous interpreter of information that serves as a self-representation of the system [49]. However, putting aside the semantic restrictions implied in our preferred use of the word "living," possible consequences of developing and deploying this novel manufacturing technology need to be considered seriously. It is intended that the "PFN will build on existing technology for chemical systems, combinatorial materials, synthetic biology, reconfigurable hardware and microfluidics, moving from 3D-printing to self-assembling architectures." To draw attention to just one aspect: questions concerning the control of synthetic biology and the ethics of its practice [18, 31] are sufficient for us to deem it a technology that cannot be safely or appropriately made available to people who have not been properly trained in knowledge of all aspects of how it operates or what its effects might be. The assessment of the potentially global, long-term effects from even seemingly minor exercises in genetic engineering is not a simple matter [47]. The tools of synthetic biology should not be available for society simply to play with, especially for individuals or groups to produce whatever serves their immediate desires in their own private sphere.

The ecological benefit of deploying a network of PFNs is not evident. In fact, the production of the necessary raw materials would likely be beset by all of the problems associated with current centralized industrial technology. Recycling materials cannot help much during expanding consumption of those resources. Even more fundamentally, energy cannot be recycled. Humanity is unlikely to be successful in creating an artificial "industrial metabolism" when it cannot adjust its behavior to fit in with the large-scale "natural metabolism" of existing ecological systems [33]. In addition to the burden that our systems place on nature, we must also consider the burden placed inequitably on some humans. Which sections of humanity will pay for the development of living technology? Will the global economic system transform itself in favor of more equitable, fairer availability of resources and opportunities as a result of the envisaged living technology being deployed? We do not claim to have any simple answer to these questions, nor do we seek any moral high ground in posing them. However, the practice of technologically oriented science can no longer be conducted as if it were a branch of *theoria*, somehow sanitized from any causal connection with social, political, and economic problems. The efforts of leading proponents of living technology to begin exploring such implications of their work in an open-minded way and in a spirit of inclusiveness, as attested to by previous published studies [4, 5, 31] and the very fact that this article appears in this journal, are acknowledged as signs that the ethical and philosophical context within which living technology is developed may be much broader than that seen previously, for example, in the case of genetic engineering.

The immediate political and economic context in which living technology is supposed to develop poses deep problems. One stated aim of the SPLiT initiative [29] is to return Europe to its former leading position in the manufacturing profile of the world. This could be interpreted as either an inappropriate reassertion of colonial ambition (a condition from which current global problems have at least partially originated) or as a grant-application device, constructed to increase the chances of the funding body supporting the research—in this case, competition for a billion euros applied to a decade of activity. New gadgetry alone, without the developers having any direct political engagement with the root social and economic causes of major global problems, such as poverty, social injustice, environmental deterioration, and climate change, is unlikely to effect a transformation that can be judged in advance to be an improvement in human behavior and engagement with the world.

We do not wish to say that the availability of new technology is of no significance in contributing to the solution of major political and social problems. In this regard we are reminded of the transition from the *samizdat* to the photocopier that was so important in improving the dissemination of information during the collapse of the repressive Soviet system; or more recently the use of cell phones in organizing the collapse of the Egyptian dictatorship. However, these examples differ from what is proposed in the SPLiT initiative in that the technology involved was at hand, not designed and developed as an unproven contribution to the solution of the overarching problems confronting the societies involved.

## 6 Transformative Technologies

At one level, any technology shows a certain ethical neutrality. Ethics arise concerning the end to which the means is applied, requiring wise regulation of its deployment [14]. However, in judging the wisdom of developing a new technology with the express aim that it is to have the capability of autonomously transforming humanity and its relationship with the world, a much deeper evaluation is necessary, starting with an analysis of what is, or ever could be, of value, either to humans or intrinsically. In this regard, the first question that we wish to raise and see discussed is whether living technology can truly be less invasive than centrally controlled industrial manufacture when it involves the forced marriage between what we have until now thought of as the living and the nonliving realms of nature. And the second, related question concerns how we judge whether living technology will contribute to improving humanity and our relationship with nature, given that an ever-growing technologically sophisticated population continues to wreak severe, unintended damage on the biosphere.

The idea of local, small-scale, democratically controlled production has a long history and was advocated in Mahatma Gandhi's proposals for the economy of India. However, it is hard to reconcile the vernacular contexts of small-scale production with the radical social, perceptual, biological, and ethical changes that truly living, adapting artifacts are likely to end up forcing on our agriculture, horticulture, and food production, not to mention our concepts of intellectual property and ownership and our domains of basic human behavior encompassing our health, sociality, and sexuality. Gandhi's spinning wheel was a bold challenge to the way the giant mills of Manchester gorged on Indian cotton, but he had no direct access to the power needed to change the situation in Britain. In a similar vein, it is not clear that free access to SPLiT-type living technology could be guaranteed for those who are economically disempowered, nor how the effects of living technology will be contained by those empowered to use it to its full extent. Technology that has been granted its own life will "read" all of the complex, intertwined aspects of humanity and nature, not according to the purposes for which it was originally designed, but according to the character of its own purposefulness, something that is integrated within it during the process of its creation.

A living thing's *own nature* is determined in part by a complex constellation of internal and external relationships and is unlikely to be contained in the particularities of easily identifiable generic features held in common with other living things according to the perception of a human designer. Furthermore, as is already evident from experience with genetically engineered organisms, knowledge of mechanisms that cause variation in such features serves as a very inadequate guide to the overall outcome of tinkering with such mechanisms to produce living things adapted to serve extrinsic human purposes. Current science perceives nature's intrinsic generative power, the "movedness" of *physis* in

Aristotle's teaching, through the lens of mechanisms that are coincident with its manifestation in biological systems. And it is now proposed to employ those mechanisms as a means of harnessing nature's most basic power for purposes expressible within the limited context of current human culture. The entities produced will presumably evolve through natural selection induced by artificial selection pressures commensurate with their design. As a result of their interactions with existing life forms, a major evolutionary transition may be induced.

Serious efforts to constrain technology so that its operation and effects are compatible with the functioning of the biosphere are very recent. They have been halting and very often obstructed by powerful interests vested in temporary economic, military or political gain. We have scant means of assessing the effect on the present biosphere of future technology whose development is most likely to be subject to very similar influences. This genre of problems has been given apposite attention in relation to genetically engineered plants by Brown [9] and Schubert [34], who judge current methods of creation and deployment to be too dangerous, but allow hope that the problems can be overcome some time in the future. Whatever the case, assessment of the potential dangers associated with new sorts of technology cannot be left to the community that is enthusiastic about their development and deployment. It is absolutely essential, in any appraisal, to involve scientists known to harbor reservations. It would be useful to consider how this would best be achieved in the models of technological development and regulation discussed by van Est and Stemerding [40].

Other technologies that have had transformative effects to one degree or another serve as instructive historical examples of how the apparently well-intended application of some novel know-how can have either unforeseen cumulative effects or drive undesirable changes on account of the larger social or political context in which they are deployed. Modern transformative technologies have developed to maturity before adequate safeguards could be instituted even against the foreseeable effects of their large-scale deployment. For example, over the course of about a century, the use of oil as a source of thermal energy has caused, or fairly directly enabled, immeasurable damage to the biosphere; and its use is reasonably implicated in global climate change. None of these effects was necessarily entailed in the creation of the oil-burning engines, but they are the result of the scale to which the use of oil has expanded, and problems with its associated infrastructure. On the other hand, the environmental problems of such large-scale use of oil could have been foreseen, but all of our societies lack such foresight or the proper means of nourishing our biological commons, with the outcome that coming generations have been left with an impoverished heritage and the unenviable task of attempting to mitigate overwhelming degenerative tendencies in their environment.

Nuclear technology provides another example. The generation of energy from nuclear processes was first applied to military ends, and the extreme effects on global security associated with that circumstance have dominated much of the last sixty-five years of human history. The exploitation of the technology for nominally civil purposes has also had extreme negative effects, most of which were foreseen. Such effects were supposed to be avoided through good regulation and industrial practice, while the public was promised a utopia in which "children will enjoy in their homes electrical energy too cheap to meter" [37]. Whatever worthy vision some of the original creators of the technology may have had, it quickly became subsumed by more powerful economic forces, and the net effects of the technology are now widely judged to have been overwhelmingly negative.

Similarly, the introduction of computers into the workplace of affluent societies was promised to deliver efficiencies in productivity that would give individual citizens more time for leisure, but the overall effect has been quite the opposite, not because of the properties of the technology, but rather because of the opportunities it has offered for countervailing alterations in individuals' work patterns. There are increasing demands for workers to document a myriad of small events electronically; working with computers has resulted in unhealthily sedentary lifestyles; many workers feel stressed and frustrated by the continual demands sent to them in the form of "information." In short, the workplace life of the average worker has not improved as promised, and the types of actual degradation in working conditions that have occurred did not give adequate cause for concern by those who exercised their power to initiate the changes. The SPLiT initiative does not appear to have the kind of safeguards necessary to help prevent similar effects.

The essence of a transformative technology is that it changes the scale of values against which its effects are assessed. Consequent upon the deployment of oil-driven machines in fulfilment of all sorts of industrial and other everyday functions, societies using them became so transformed that what individuals considered "normal" also changed unrecognizably. Thus, the value in everyday life of transport, agricultural products, processed and manufactured goods, and various machine-dependent leisure activities changed radically as a result of the availability of oil as an apparently boundless source of thermal energy. However, eventually another value also came explicitly into being and is now the dominant motif in most considerations of the wider effects of any technology: global sustainability. What had previously been taken implicitly as an inherent property of nature has been challenged to such an extent that humans scarcely have the means to restore it. In this process human culture has tried to take possession of an intrinsic value of nature and ended up holding the remnants of it in its own hands. The value that global sustainability once had intrinsically for the whole biosphere has been transferred to a human assessment of it, and awaits mitigation of the worst effects of its breakdown.

In the case of living technology, it is necessary to develop a conception, before anything potentially useful is ever created, of how the commercial production, distribution, and use of its artifacts will occur within the context of our global society. Consideration must be given to the realities of how power is exercised in the realms of international and local commerce, environmental protection, and so on. However, the lessons to be learned from the previous transformative technologies we have mentioned will not be enough. None of those was envisioned or designed as a transformative generic technology capable of opening up new fields of human endeavor involving the detailed control over material at the molecular or submolecular level. Only genetic engineering is comparable, a technology less than half a century old whose main effects may manifest themselves after some millennia [46, 47].

The possibility of living technology calls for an even more precautionary approach. In relation to the products of genetic engineering being deployed in the biological commons, humanity has not devised the safeguards necessary to protect the diversity of species that has evolved in the biosphere. If the preservation of the diversity of species is taken as a prerequisite for the survival of the essence of species themselves, then the biosphere faces unprecedented danger from human behavior that threatens its inherent diversity. In the case of living technology it is also necessary to consider the diversity in systems of societal self-organization and belief that define different cultures. Living technology is bound to induce a new, globally normalizing conception of "living" that will be profoundly at odds with ways of life not rooted in a scientific, technological way of thinking.

## 7 Biology and Ethics

In his discussion of the nature of technology, Fischer [14] makes extensive use of the philosophical anthropology of Plessner [30] to justify discussing technology and its relationship to biology as something peculiarly human, and therefore having an unavoidable ethical dimension. While the life of plants is characterized as being externally controlled, governed purely according to the law of growth, and that of animals as having an autonomy that derives from their bodily mobility and integrated sensory systems, humans are characterized by the ability to perceive their internal representations reflexively, as something from which they are separate. Thus, the fundamental human experience is that of transcending whatever is given as phenomena in the outside world: an existence that presents itself as inescapably *artificial* in comparison with the world of nature, taking what is simply natural to include internal reflexes and instincts of whose operation we are not immediately conscious—a part of human nature shared with other animals. D. R. Wills [44] asks whether this animal reaction could be understood in terms of a natural automatism, something inanimate, that precedes it, a "technological necessity lodged in life itself." The experience of taking something from its "natural" state and turning it into an "artificial" means for the accomplishment of purposeful ends is an extension of the ordinary, natural, human experience of subjectivity—the internal self that "sees" the external world; and then technology is simply the cultural systematization of applying whatever means humans find naturally at their disposal.

Humans have the ability to take, as a target of reflective perception, an internally held representation, such as the purpose of some possible action. Thus a human can take an internal mental image or process as an object just as surely as he or she can take a body part, such as his or her own hand, arm, or leg, as an object of sensory perception. And with that access to reflection on internal representations comes the further possibility of reflecting on the relationships between representations of different purposes and the evaluation of them according to some scale of value. Thus, the inescapable moral dimension of human consciousness is inextricably tied to the possibility of technology. Both derive from the fact that humans have access to representations of internally defined purposes as objects of reflective perception. Technology is created through a calculus of how the world can be arranged to facilitate the accomplishment of those internally represented purposes—the art of determining in advance what nature will allow, so that particular outcomes can be set up to occur. The ethical dimension of being human comes to the fore in situations where not all outcomes are simultaneously achievable, necessitating a system for evaluating different intended ends relative to one another, including quite abstract ends like keeping various options open—especially, keeping something alive. Cultures give expression to ethical norms by negotiating, often implicitly, scales of value that ultimately form part of the social fabric.

What is a thing and what is it worth within any context? In the thinking of Socrates and Plato, ethics are founded on the notion of a thing's inherent worth, which establishes the standard according to which the thing should be treated. The basic idea has persisted for millennia and has recently been interpreted in such a way as to imply that it is inherently connected to the modern scientific description of living things. For example, the New Zealand Resource Management Act (1991) requires various persons to have particular regard to the "intrinsic value" of ecosystems, which is taken to mean "those aspects of ecosystems and their constituent parts which have value in their own right, including—(a) their biological and genetic diversity; and (b) the essential characteristics that determine an ecosystem's integrity, form, functioning, and resilience." If we are to consider the application of a very general principle of this sort to the ethical ramifications of living technology, then we first need to investigate the idea of intrinsic value a little further. In this regard it is pertinent to ask how intrinsic value might be associated with different things found in nature and how such value might be construed to correlate with a thing's character.

Consider the reasons why an electron, a crystal, a bacterium, a plant, an animal, a person, an ecosystem, a human culture, or the biosphere as a whole might have inherent worth or intrinsic value. A description, framed in terms of mechanical, material principles, would seem to give a complete account of any interaction between an electron, or a stone, with anything else. It makes little sense to consider what meaningful representation of itself or any aspect of the world around it an electron or crystal might carry as a mark of its value. The imperfections in a crystal could represent historical events during its formation, but the crystal lacks any means of interpreting that representation or projecting it onto a scale of relative value. Inherent worth or intrinsic value cannot be ascribed on the sole basis of material composition. However, in the case of a bacterium or plant, there are internal molecular parts that bear functional relationships to one another. These functional relationships play essential roles in the organism's interactions with the world of its surroundings, its *Umwelt* [41] and in the maintenance of its life. When it comes into existence, an individual organism inherits a panoply of internally ordered relationships between material components that are necessary for its continued existence, its life. It also inherits a store of genetic information, a code script for its internal control, the execution of which directs maintenance of the living order. This special material order, this "life" that the organism has, is the thing that exists and is of value to itself for the very purpose of existence: to be what it is, to survive, to live, as opposed to being nonliving, or dead. Seen in this way, every living thing has value in itself and for itself. In other words, it has intrinsic value, first measured relative to the most elementary alive-dead binary scale in reference to which its spatiotemporal, material state can be determined.

Just as all living things, and even life itself, can be thought of as having intrinsic value, so can sentience and consciousness. Thus, the intrinsic value of an animal is tied to the fact that it is alive and sentient, and it is these facets of animal existence that have to be taken into account in the ethical treatment of them. Likewise, the ethical treatment of an individual human requires cognizance of the person's life, sentience, and consciousness, which are each facets of human existence, perhaps hominid existence generally, that confer intrinsic value on an individual. Consciousness of purpose, the internal representation of some potential future outcome, is the most immediate experience an individual human has of intrinsic value—that of one's own life. (Only through suicide, the deliberate ending of one's own life, can the continual evaluation of future outcomes purposefully be put to an end, and any self-assigned value denied with ultimate effect.) However, considering intrinsic value only in relation to individuals is very restrictive and provides only part of the picture that is required in relation to the ethics of technology. The life of any individual organism can only be maintained as long as the life of a broader ecosystem is maintained—the animal kingdom could not exist without plants being available as food. Similarly, a person's consciousness depends constitutively on a myriad of culturally mediated experiences, including language, and a host of processes of psychological conditioning, all of which continually contribute to the individual's identity and well-being. Because ecosystems, cultures, and the biosphere as a whole are determinants of their own survival and contextual prerequisites for the existence of individual things that have intrinsic value, they too are vessels of intrinsic value that any ethical scheme must address.

## 8 Ethics of Living Technology

Discussing the ethics of living technology necessitates using the language of teleology. Whatever is used is used for a purpose; whatever is constructed has potential purposeful uses. To talk about technology and thereby attribute purposefulness to human activity, even implicitly, and then deny that purposefulness exists in nature, of which humans are a part, would be logically inconsistent. The relationship between a system and an object it uses as a tool, part of itself even, is not a mere matter of spatiotemporal coincidence, of the mechanics of matter. The relationship requires that the system include some sort of information in which the tool is represented. The genetic encryption of information about the enzymes used by cells to match amino acids to cognate tRNAs, thereby producing the genetic code, is perhaps the most primitive example of a system-tool relationship [49].

The aim of living technology that goes far beyond the mere biomimetic is to make a tool of some of the most fundamental properties of nature, the potential purposefulness that accompanied the emergence of informational representations and information processing at the origin of life. The central question to be addressed is how, or even whether, living technology will recognize the intrinsic value of what it makes use of and what it affects. Do the most basic features of molecular biological processes, exactly what living technology seeks to turn to human use, have intrinsic value? Without it having been asked so explicitly, this question has dominated the conflict between supporters and opponents of applications of genetic engineering in various agricultural, horticultural, pharmaceutical, medical, and commercial projects. For most supporters of the technology the question signifies a "category error." It is seen as nonsense by them because the human idea of value bears no relationship to what can be described adequately in terms of the behavior of biomolecules and their interactions. The assignment of value to molecules and their interactions and arrangements is deemed to be utterly arbitrary, whereas many opponents of genetic engineering protest that recognition and protection of intrinsic value, even at the level of DNA sequences, is a high ethical duty [48]. To try to take possession of those most basic parts of the natural world (genetic representations of biological possibilities, without which intrinsic value could not have come to terrestrial expression), to take hold of the processes in which it was first manifest and harness them, "from the bottom up," especially to serve the finite goals conceivable and achievable by twenty-first century humans, is an affront to intrinsic value at its source, nature itself.

This seemingly impassable ideological divide, between those who wish to recognize intrinsic value as something natural and those who do not, coincides roughly with the definition of a number of intellectual and political groupings in contemporary global society. For example, most molecular biologists, steeped in the reductionist assumptions that have underpinned the rapid developments in their discipline over the last sixty years, belong to the former camp, along with the majority of those invested with economic power and/or the authority to regulate the practice and international control of genetic engineering and its products. By way of contrast, most of those who support "bio/organic" markets, whether as producers, consumers, or political protagonists, are found in the other camp: they wish to preserve biospheric metagenomics from the self-perpetuating effects of large-scale human interference. By and large, the exercise of formal power lies with the reductionist ideology, and those who dissent from it have little direct effect in decision-making processes, tending to exert political influence in more diffuse ways.

The main legal instruments that sustain the power of the reductionist ideology vis-à-vis the modification of the global commons with genetically engineered products are laws concerning patents and intellectual property in general. In many jurisdictions genetic sequences can be owned by persons, so that their possession or use in the form of nucleic acid molecules in biological systems by non-owners is severely restricted and subject to financial costs. (The qualification concerning instantiation in nucleic acid form is necessary because there is generally no restriction on use of the information per se, e.g., in electronic, optical, written, or printed form.) Human ownership of "genetic resources" is an arena of intense international and corporate competition. It is a major focus of modern commerce. At the other extreme, we could envisage a future in which ownership of genetic sequence information is thought about with universal abhorrence, the way we now regard the most oppressive form of secondary living technology conceivable: human slavery, the ownership of one person by another.

If living technology actually becomes much more sophisticated than present-day genetic engineering, one might expect the intellectual and ideological conflicts to intensify. Proponents of living technology intend not only to modify systems by introducing novel genetic sequences into them, but also to fit them with new, self-sustaining ways of interpreting their genetic complement. If not that, they intend at least to exploit knowledge of the information-interpreter couplings found in nature, in order to design systems with a physical and functional autonomy that has been the exclusive heritage of organisms until now. In the current economic climate it is hard to imagine living technology of this envisaged form being created beyond the need to return significant financial gain to whoever has paid for its development. And that means conforming to the demands of markets that are driven, exploited, and manipulated by corporate interests, whose operational aim it is to vest themselves with an increasing share of global power, constrained less and less by sanctions that can be imposed by national governments. The final determinative factor in market success is ownership, which entails the right, according to whim, to enforce restrictions on access by other persons. Restrictions on access to and claims of ownership of resources not only are at the root of much injustice and conflict among human societies, but also hinder many efforts to contain the destructive and unsustainable exploitation of nature. Unless living technology can somehow emancipate itself from these problems, it can be expected to exacerbate them by putting even more power into hands whose work has not displayed a sense of responsibility commensurate with nature's intrinsic value.

Given the political and social context of living technology's potential creation, we do not recommend setting off on the path to create it, in the faith that it will bring about a better future. Even if technology could truly be brought to life, it would not possess intrinsic value in the manner we have described for biological organisms. To return to the analysis of Aristotle and Heidegger, the *telos* of an organism, the coincident origin and end of its existence, is internal to it. It has value for itself, intrinsic value, that is derived from *physis*, the "movedness" of nature. In stark contrast, the value of something that is produced for a purpose, brought into existence in conformity with some prior conception of how it appears to the producing agent, is to be found in the coincidence of an origin and end that are external to it, the *eidos* that precedes its generation. Thus, the bringing together of the intrinsic value of an organism and the extrinsic value of a technological creation in a single entity poses special ethical problems. How are the relative intrinsic and extrinsic values to be judged? As has been argued elsewhere [48], humans should take a much more generous approach, what might be called *precautionary*, in affording to other species the recognitions, rights, and protections of intrinsic value, such as we have gained for ourselves through long and painful historical processes.

The way scientists use their know-how to create new possibilities is embedded in a matrix of global problems whose ethical aspects not only supersede those of the local context in which the technology is being developed, but also feed back to become the main defining features of the ethos that drives the technological development. It seems unnecessary to wait until living technology becomes ready for deployment to consider these implications. Before we humans set about transforming nature and ourselves, we need to take a very close look at why we want to do it and what the transformation will mean for both humanity and nature and for the relationship between them. We do not consider that human society is currently capable of manipulating the fundamental processes of life in such a way as to cause them autonomously to fall in line with any very worthy purpose. There may be but few scientists who share our point of view, but we hope for the deepest possible enquiry into challenging questions of the sort: "In what potential ways could current conceptions of living technology, those being proposed and acted on now, turn out later to have been based on profound ignorance?"

## 9 Discussion

The central question bearing on the ethics of living technology concerns the way in which human purposefulness is a part of nature—because that is precisely what is being proposed for change. What will it mean for humans to take the most basic quality in nature from which their own particular purposefulness is derived—the principles of biological self-organization—and put this at the disposal of human purposes? The question is not a scientific one, but it goes to the heart of contemporary practice in molecular biology and biotechnology, and the role they play in global society. The undesirable tendency that we see in all that we have described concerning modern technology is that it is becoming a fetish. Humanity wants every possible means put at its disposal, even when those means are not required for any established purpose, or even properly defined. Science is rapidly becoming a playing with technology, rather than a way of pursuing knowledge concerning nature. Its promises of continued "improvement" in human life become self-fulfilling prophecies as the value of that life is continually redefined in terms of a relationship with the newest technology. Ends become confused with means, and needs with wants, at least among those parts of human society economically privileged enough actually to construct the objects of their dreams—a tendency the SPLiT initiative proposed to democratize.

Having followed the analysis of Heidegger [20, 21] as far as his conclusion that modern technology does not lead humanity into an authentic relationship with nature, we wish to comment on what answer he might offer to the question: "What could? Living technology?" According to Riis [32], an unexpected reconciliation between modern technology and the ancient conception of *physis* is to be found within the interstices of Heideggerian thought and is offered specifically by living technology. We have concluded the opposite. The potential danger of living technology exceeds that of anything current, because it would open the way for all of life, including that of each conscious individual, to be understood by analogy with something created to serve finitely conceived human purposes. Living technology poses the extreme danger of our losing the capacity to comprehend ourselves in any way other than as *Bestand*, a technological resource [21]. We now turn to the philosopher's posthumous legacy [23] to outline what we consider to be critical limitations in his thinking about the way out of the danger posed by modern technology.

Heidegger [23] ascribes an autonomous logic to technology, characterizing it as "something that man does not master by his own power." In the end he declares that "Only a god can save us" because all merely human meditations and endeavors will not bring about a direct change in the present state of the world. He had previously written that "No single man, no group of men, no commission of prominent statesmen, no conference of leaders of commerce and industry, can brake or direct the progress of history in the atomic age" [22], recommending, in place of action, the passivity to be found in meditative thinking. And the task of thinking is "precisely in this, that within its own limits it helps man as such achieve a satisfactory relationship to the essence of technicity" [23]. However, Heidegger could not avoid acting with political effect, and in relation to the endeavor with which he once aligned himself he continued: "National Socialism did indeed go in this direction. Those people, however, were far too poorly equipped for thought to arrive at a really explicit relationship to what is happening today and has been underway for the past 300 years."

There has been much debate concerning Heidegger's complicity with the Nazi movement [28, 51] and its connection with his view of technology as human destiny. His final assessment of National Socialism was that it had an "inner truth and greatness" to do with "the encounter of planetarily determined technology and modern human beings" [23]. Thus, he never repudiated the effects of his many dubious actions during the period 1933–1934 in his role as the Rector of the University of Freiburg [28], when he failed in the difficult, inescapably moral task of engaging fairly with the exigencies of real-world politics. As a result, his actions, and consequently the application of his thought, became associated with the works of Hitler, rather than some more worthy history-maker, for example, Gandhi. In our view, Heidegger's thought brings humanity to a point where ethical action becomes an absolute demand, but it totally fails to show an appropriate way forward.

We do not presume to dictate how an individual should act under circumstances in which dissent might result in the loss of his or her life, but we are prepared to suggest some norms of behavior under less extreme circumstances. In relation to new technological possibilities, there seems little hope in time of war, or dire threat, of changing the direction of science so that it contributes less, rather than more, to the development of means that can be misused for destructive purposes. The skill and work of scientists and technologists is critical with respect to the most undesirable of human interactions: warfare and the repression of ethnic or national populations. The development of living technology, should it be possible, will open up completely new vistas in such areas. For whom should such possibilities be available? Our answer is an unequivocal "no individual or collective agency whatsoever" because the use of life's core principles to produce instruments of division and destruction would be the end of what we understand to be humanity.

The only way left for modern technological humans once again to appreciate our relationship to what the ancient Greeks called *physis*—the generative power of nature—is for us to start to understand our natural limits, to hold back the urge to know and produce everything possible, desired, or apparently necessary. Holding back should not be construed as mere passivity, but rather as a form of reengagement with that in our nature which makes technology possible in the first place. Writers such as Feenberg ([12]; see also [39]) hold out hope that technology can be reformed through democratization, starting with active political and ethical engagement, not the creation of new gadgets. And that is precisely the attitude we take toward living technology. As a token of our position, we wish to add a well-established endorsement [45, 49] to our contribution:

> It is the authors' wish that no agency, individual or collective, should ever derive military or purely financial benefit from the publication of this paper. Authors who cite this work in support of their own are requested similarly to qualify the availability of their results.

We hereby issue a challenge to our community of scholars to take collective action now in an effort to prevent life's core properties ever being exploited for destructive or antisocial purposes at any time in the future. If such exploitation were to occur, it would be better not to have sought to develop living technology in the first place. That is the position of antecedent responsibility in which we find ourselves.

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