<u>Synthetic Biology, Nanotechnology, and the Death of Environmentalism</u>

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I. A Distinction Essential to Environmental Philosophy

Two years shy of celebrating the 150 year anniversary of the publication *Origin of Species* – a book without which it is hard to imagine either modern biology or modern environmentalism existing in any recognizable form – synthetic biology and nanotechnology threaten to render important elements of Darwinism irrelevant. With these threats looming, those for whom the idea of the "historical evolutionary process" comes with any kind of normative punch have some serious self-reflection to do. Many environmentalists are about to lose one of their favorite philosophical ideas.

This is not the first alarm call sounded about the death of an important philosophical idea. Most famously, Bill McKibben gave warning in 1989 of "the end of nature" due to anthropogenic climate disruption. Ideas, like animals and plants, McKibben warned, can go extinct. In McKibben's argument, the idea is "nature," a term standing for "the separate and wild province, the world apart from man to which he adapted and under whose rules he was born and died" (48). Following McKibben, other thinkers have sounded a similar warning. Keekok Lee has cautioned how deep technologies such as nanotechnology and biotechnology are "nature-replacing" and threaten the very existence of the natural world as we understand it (1999, 2003). Pairing McKibben with other more complicated (though less literal) threats from deconstructive

theory, Steven Vogel has also warned us to prepare for environmental philosophy "after the end of nature" (2002).

In all of these cases, the entity under threat is an object. That object is nature. Though the nuances of the arguments differ, each of these sentinels alerts us a deep loss to which we will need to adjust. This paper is also about a threat of deep loss, but it is not the loss of any particular object. It is about the loss of a connection to a process. Moreover, the connection being lost is one without which it is hard to conceive of certain positions in environmental philosophy making any sense at all.

II. At Stake for Environmental Philosophers

A large number of positions in environmental philosophy rest on a substantial normative commitment to the value of what is natural over what is artificial. This commitment extends beyond environmental philosophy to play a considerable role in environmentalism as a whole. Good environmentalists pay plenty of attention to issues of human health and well-being, both in the current generation and in future ones. But if such an environmentalist lobbied exclusively on behalf of human health and well-being, and did not flinch when this advocacy came at the direct cost of the well-being of natural systems, wild animals, and wilderness lands, many would suspect that there was something missing from their environmentalism. For a large proportion of those in the United States who call themselves "environmentalists," nature is an essential object of moral concern. David Lowenthal characterized this normative commitment at the birth of the modern environmental movement as follows:

> "Nature is…thought preferable to artifice. The favored landscapes are wild; landscapes altered or disturbed or built on by man are considered beneath attention or beyond repair." (Lowenthal 1968: 81).

To sustain this line of thinking, the small matter of how to identify the natural and mark it off from the non-natural (or artificial) has always been central to environmental thinking. Typically, environmental philosophers have put great stock in the distinction made neatly by Aristotle more than two thousand years ago. In *The Physics*, Aristotle characterized natural objects as those that have within themselves "a principle of movement (or change) and rest" (*Physics*, 192b8-11). Any change the object undergoes over time is determined from wholly within that object's nature. Acorns grow into oaks, humans grow grey hair and stoop, and mountains slowly erode. An artifact, by contrast, lacks "the source of its own production…that principle is in something else external to the thing" (*Physics* 192b28). The external source to which Aristotle refers is the intentional action of a human. Artifacts display the presence of human intention in them whereas natural objects do not. Keekok Lee, anchoring a good deal of her work entirely on this distinction, usefully summarized Aristotle's point this way:

> "'[T]he natural'…refers to whatever exists which is not the result of deliberate human intervention, design, and creation in terms of its material efficient, formal, and final causes….The natural comes into existence, continues to exist, and goes

> out of existence entirely independent of human volition and manipulation." "By contrast, 'the artefactual' embodies a human intentional structure" (1999: 82).

The apparent simplicity of Aristotle's distinction has enabled environmental philosophers to quickly latch on and layer it with normative additions. This emphasis on the normative significance of non-humanized nature has been particularly prominent for non-anthropocentric environmental philosophers. Robin Elliot pointed out how "we value the forest and river in part because they are representative of the world outside of dominion, because their existence is independent of us" (Elliot 1982, 86). Eric Katz claimed simply that "value exists in nature to the extent that it avoids modification by human technology" (Katz 1992, 265). Bill Throop and Ned Hettinger, championing the value of wildness, claimed "something is wild in a certain respect to the extent that it is not humanized in that respect" (Hettinger and Throop 1999, 140). All of these thinkers have pointed to the fact that the *naturalness* of nature, in Aristotle's sense, carries deontological moral weight.

But the apparently simple way that Aristotle's distinction serves environmentalists is, of course, an illusion. The problems inherent in distinguishing the natural from the artefactual have long been known to environmental philosophers. In his 1874 essay "Nature," John Stuart Mill noticed immediately the paradoxes. On the one hand, human actions are natural because they do not transcend natural laws. Yet at the same time, Mill saw how everything a human does by definition leaves nature in a non-natural state.

Mill's essay was just a hint of a whole raft of problems for environmentalists' use of Aristotle's nature/artifact distinction. The distinction simply cannot do the work

modern environmentalists want it to do. The complexities emerge as soon as an environmentalist tries to discriminate between artifacts. Not all objects containing human intention are environmentally bad. Many are of relatively low or benign environmental impact. A hut made of clay and thatched grass in Africa's Rift Valley contains human intention no less than the US interstate highway system, or the Glen Canyon dam. A restored wetland or a landscape created by a prescribed burn are artifacts, containing considerably more human planning and theoretical sophistication than, say, a Walmart parking lot. In terms of the amount of human intention they reflect, environmental blessings such as photovoltaic panels or modern wind turbines have more in common with PCB's and polluting SUV's than they do with pristine watersheds and free roaming wolves. Aristotle's distinction seems completely incapable of capturing such differences. It is far too crude to serve an environmentalist's normative agenda adequately.

Unfortunately, the problems don't stop with the issue of crudity. In North America and beyond, it has been well documented how the distinction (when carelessly managed) leads to frightful kinds of ethnocentrism and racism. "Natural" landscapes, apparently unmodified by human activity, are widely thought today to have been an immigrant American's fantasy, an error that has led to the denial of indigenous histories written across numerous ecologies. The problem of its crudity and of its connection with ethnocentrism seriously undermines the workability of Aristotle's nature/artifact distinction for environmentalists. For these and other reasons, Vogel might turn out to be right in his suggestion that environmentalists drop their reliance on ideas like "nature" and "the natural."

But the idea of nature unmodified by human activity is so central to environmentalism that its advocates would have a hard time letting it go. The emotional connections run deep. The history of the North American environmental movement cannot be so abruptly rewritten. As a matter of political reality, the idea that wild nature is morally significant is one that motivates millions of people. Just dropping the idea of nature and the natural world is politically unimaginable. There are also important non-pragmatic reasons to retain the idea of nature. Nature unmodified by human intention may be increasingly hard to find today. But as a matter of historical fact, there were over 4.6 billion years of geological history on Earth that preceded the arrival of our first, artifact-creating ancestor, *Homo habilis*, approximately 2 million years ago. During these 4.598 billion years of earth's history there were processes at work ultimately responsible for creating everything environmentalists find of value today. For 4.598 billion years, there really was (as a matter of historical fact) something one could call "nature" in an unproblematically Aristotelian sense. This fact is incorporated deep within many environmentalist sentiments for protecting nature.

For about 80% of that long reach of time, there has also been something one could call the "natural historical evolutionary process" working its effects on living beings. As Darwin explained in 1859, natural variations appearing in successive generations of biological organisms will tend to be preserved if those variations provide survival or breeding advantage. Over the millions of years of evolutionary history before the arrival of hominids, that process created great biological diversity and complexity. This long history of variation is ultimately responsible for creating the species and the ecologies that environmentalists seek to preserve today. It is for good reason that many

environmental philosophers think this historical process morally important. In some ultimate sense, this process is responsible for everything we value, both in human society and in the natural world. Part of the reason we protect wildlands, claims Holmes Rolston, III, is that it provides "the profoundest historical museum of all, a relic of the way the world was during 99.9% of past time" (1988, 14). Eugene Hargrove, pushing a quite different aesthetics-based approach to environmental protection, also suggests "nature aesthetically is not simply what exists at this point in time; it is also the entire series of events and undertakings that have brought it to that point. When we admire nature, we also admire that history" (1989, 195). This blending of historical fact and normative significance is why the idea of nature non-humanized needs to be retained. The question is how to do this in the face of the nature/artifact distinction's acknowledged problems.

III. Keeping the Nature/Artifact distinction significant

Though she may not see her work in quite these terms, Keekok Lee suggests a way to retain the heart of the nature/artifact distinction is by side-stepping the problems of its crudity and its ethnocentrism. In two works about what she calls "deep technology," Lee asks us to distinguish the effects of "nature-replacing technologies" from the effects of what are simply "nature-polluting technologies" (Lee 1999, 2003). Nature-polluting technologies, Lee claims, can be harmful towards nature but only in the sense that they might adversely impact nature's ecological functioning. Since the early days of the industrial revolution and the airborne particulates in cities such as Manchester and Pittsburgh it was clear that technology had the potential to damage both environmental and human health. But this damage, Lee claims, is relatively superficial.

Better, less polluting and remediating technologies can often mitigate these negative effects if the political will is present. In Manchester and Pittsburgh, the air has for the most part been cleaned up using a combination of new laws and new technologies.

According to Lee, other technological threats are not so easily defeated. Molecular nanotechnology and biotechnology, she claims, manipulate nature at such a fundamental level that they pose an altogether different kind of problem. Rather than just modifying nature, these "deep technologies" replace nature with something entirely different (Lee, 1999, 2003). Nanotechnology re-orders nature at the level of the atom or the molecule (approx. $1 \times 10^{-9} – 1 \times 10^{-7}$m). Biotechnology manipulates nature at the level of the DNA molecule. By working at these fundamental levels, Lee claims that nanotechnology and biotechnology effect a transformation of nature of an entirely different kind.

The threat of these technologies is not, according to Lee, primarily in their potential to pollute. In fact, there is some hope that molecular nanotechnologies can substantially reduce pollution.[1] The cost of nanotechnology and biotechnology, according to Lee, lies in their capacity to "systematically transform naturally occurring beings (whether biotic or abiotic) to become artefactual ones" (1999, 1). These technologies don't just transform natural materials into objects that can be put to some use. They transform the natural materials themselves, changing natural kinds into artifacts. "Humans in the possession of nanotechnology," she states with concern, "are in a position to systematically replace natural abiotic with artificial kinds if and when it suits their purposes to do so" (118). A structure made out of carbon nanotubes, synthesized at

[1] The actual level of threat of pollution posed by different nanotechnologies remains relatively unknown. Suffice to say there is reason for some serious concern.

the molecular level, is more of an artifact than a wooden table. Its very molecular arrangement has been synthesized. Similarly, thinks Lee, Bt corn, genetically manipulated to resist pesticides, is the deepest kind of biotic artifact. Its very genome is the product of human intention.

As "nature-replacing" technologies, Lee claims both nanotechnology and molecular biotechnology constitute "a radical threat to the ontological category of the natural" (114). Ultimately resting her sense of loss entirely on a traditional usage of Aristotle's distinction, Lee points out that these technologies represent "the ultimate humanization of nature" (118), creating ultimate artificity. Such a result, according to Lee, would result in a dramatic "ontological impoverishment" (119). For deontological reasons, then, molecular nanotechnology and molecular genetics should be opposed.

IV. Lessons from Lee.

Lee's objection to deep technologies contains both insight and difficulties. The insight is that at if environmentalists are going to retain Aristotle's distinction in any useful way then they are going to have to figure out a means for discriminating between human modifications of nature that are in some sense problematic and modifications that are superficial or even, in the case of artifacts such as restored wetlands, desirable. Lee's strategy, that of searching for specific types of manipulation of nature more fundamental than others, seems like a helpful direction to go. The difficulty is to figure out just what is to count as a more fundamental transformation. And here Lee does not do so well.

In the case of abiotic nature, the suggestion that the creation of new kinds by molecular nanotechnology is morally problematic is contentious in the light of existing

accepted practices. Synthetic chemistry has been creating new kinds of materials for hundreds of years through the rearrangement of molecular structures. According to Joachim Schummer, the creation of new materials in this field occurs at a rate of around 900,000 new materials a year (Schummer 2001). Plastics are themselves new kinds. And while environmentalists are correctly leery (for prudential reasons) of the kinds of harm plastics might cause to the ecological functioning of the environment, it seems doubtful that plastics are ontologically pernicious in themselves. There is little reason to think (as Lee does) that molecular nanotechnology should provide any more of a moral challenge than existing synthetic chemistry. In fact, the late nano-pioneer Richard Smalley, in a long-standing debate with Eric Drexler, insisted that nanotechnology is often little more than a matter of careful chemistry.[2]

Part of what lies behind this objection to Lee's argument is a doubt about whether simply the scale of the manipulation of nature can make any morally relevant difference. Even if nanotechnology aims to change nature by working at the level of the atom or molecule rather than at larger, more familiar scales, it is not obvious why this should have any particular moral import.

In the case of biotechnology, the creation of new biotic kinds may also not be the problem Lee thinks it is. One reason for questioning the moral significance of manipulating a genome is the known fluidity of the concept of a species. Since the beginning of Darwinian evolutionary theory it has been clear that species are not fixed kinds but transient assemblages composing and shifting over time as the individuals that make them up die out, change habitat, mutate, and adjust incrementally – and sometimes

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[2] The so-called "Drexler-Smalley Debates" in nanotechnology suggest the distinction Lee makes here is more complicated than she assumes. Smalley sees molecular nanotechnology as nothing more than a matter of careful chemistry.

relatively rapidly – in response to environmental stressors. Darwin himself warned "I look at the term species, as one arbitrarily given for the sake of convenience to a set of individuals closely resembling each other." (Darwin 1968, 108). If, as Ernst Mayer claims, species are only "groups of interbreeding natural populations that are reproductively isolated from other such groups" (Mayer 1969, 26) then it is not clear why there would be anything particularly morally significant about such contingently assembled populations.

A second clear reason why the creation of new biotic kinds may not be a moral problem is that humans have been creating biotic artifacts for thousands of years. The hybridization of crops and the domestication of animals is a perennial thorn in the side of those wishing to make deontological arguments against biotechnology. Deontologists have to show how modern genetic manipulation is different in kind from traditional selective breeding. Lee thinks the distinction can be made because of the difference in the degree of manipulative control in modern biotechnology compared to traditional hybridization. She suggests there is "a quantum leap in the level of artifacticity" between projects relying on a breeding program steered by the principles of Mendelian genetics and the laboratory techniques used in modern molecular DNA technologies (2003, 148). The rate, scope, and degree of transformation are all enhanced by molecular genetics. Transgenic organisms are a case in point. Without molecular biotechnology there would not be tobacco plants that glow because they contain genes from fireflies.

But deontological arguments such are Lee's are not convincing to everybody. If naturally occurring genomes have been artificially changed throughout human history, why should there be a marked difference between today's changes that occur in a

laboratory and yesterday's that occurred in a farmer's field or barn. In both cases what takes place is the intentional manipulation of the inherited genetic material of a biological organism. As in the case of molecular nanotechnology, the only difference appears to be the scale and the method of the manipulation. If it all boils down to scale, then it is hard to see how this provides an adequate deontological objection.[3]

In addition to the questionable quality of the deontological argument against molecular biotechnology there is a practical consideration growing in significance with each passing year. Just as it is almost impossible to object to traditional selective breeding today on the basis of its having been around and accepted for millennia, so is it becoming increasingly hard to object to genetically modified organisms. In 2003, one hundred and sixty-seven million acres of genetically modified crops were planted world wide, with 65% of those being planted in the US. US farmers produce genetically modified corn, cotton, soybeans, canola, squash, and papaya for domestic and export purposes. Over 85% of soybeans and 76% of cotton grown in America is already genetically modified.[4] The genie appears to be already well out of the bottle. The deontological objection is already sounding rather passé.

Reflecting the shakiness of the deontological arguments, most of the opposition to late-twentieth century genetic biotechnology tends to be made on prudential rather than deontological grounds. Much is made of the potential harm of bio-engineered crops and species on native ecosystems as a result of the replacement of historical biodiversity with engineered organisms. In addition, the potentially devastating effects of biotechnology

[3] Gary Comstock identifies a number of additional deontological arguments including i) playing God, ii) illegitimately crossing species boundaries, and iii) commodifying life (2002, 93). I skip these arguments here in order to get to a distinctive argument against synthetic biology in Section V.
[4] Pew Initiative on food and biotechnology, available at http://pewagbiotech.org/resources/factsheets/display.php3?FactsheetID=2.

on indigenous knowledge and on local economies have been well highlighted by Vandana Shiva (1993, 1999) and others.

At this point we are no further along in retaining a problem-free environmental use of the nature/artifact distinction. There are problems with its use to condemn the creation of artifacts both in the case of traditional modifications of nature – such as using saws and chisels to shape wood – and in the case of modifications that result from what Lee calls "deep technologies." It is worth asking whether there is any remaining good use that environmentalists can make of it for their normative agenda. I have suggested that philosophers will need to keep the distinction at the very least for the purposes of having a signifier for the 3.598 billion years of evolutionary history before the arrival of *homo habilis*. And though I have not dared enter the morass here, it seems likely that some notion of "degrees of naturalness" will be useful from distinguishing Rift Valley mud huts from Walmart parking lots. But is there any technological arena in which environmentalists can still safely use Aristotle's distinction in its unmitigated form to raise deontological objections to the products of that technology?

My answer is "yes" and my claim is that the arena is "synthetic biology."

V. The last stand for Aristotle's distinction

Synthetic biologists propose to mix and match DNA and insert it into single-celled organisms to perform desirable functions such as the creation of insulin for medical applications, the decontamination of waste, and the production of methane or ethanol for energy projects. Synthetic biologists combine isolated DNA sequences with desirable functions (known as "bio-bricks") to form useful living organisms. Synthetic

organisms are built up by adding these bio-bricks to a bacterium to produce viable biological entities that can perform certain tasks. These are still relatively early days of the research. Nevertheless, Israeli scientists have engineered DNA to carry out basic mathematical functions that could theoretically be integrated into functioning computers. A Princeton University team has made an artificial organism within an *E. coli* bacterium that blinked predictably. Both teams engineered a machine to perform a chosen function, with the product of their efforts located entirely within a living cell. Synthetic biology is therefore often appropriately characterized as precision engineering applied to life.

One of Lee's main objection to molecular nanotechnology was its ability to "construct *de novo* synthetic, abiotic kinds, from the design board" (1999, 118). Synthetic biologists do exactly this with biotic, rather than abiotic, kinds. The idea of redesigning life using engineering principles is the overall framework under which synthetic biology operates. The rhetoric used by synthetic biologists reveals just how ambitious are their construction projects. "Think of it as Life, version 2.0" said an article in *Scientific American* in 2004. The challenge synthetic biology offers to the historical evolutionary process is often fairly explicit. Craig Venter, a synthetic biologist who earlier headed the consortium that mapped the human genome, is described by a critic as desiring to "short-circuit millions of years of evolution and create his own version of a second genesis." Others share this goal of replacing evolution with something better. "It will be a marvelous challenge to see if we can outdesign evolution" offered George Whitesides 2001.

The relevant difference between synthetic biology and traditional biotechnology is that the latter starts with the genome of an existing organism and modifies it by deleting

or adding genes. The scientist takes viable organism and makes a selective change, hoping in the process not to modify the existing organism to such a degree that it is no longer able to survive. In every case in traditional biotechnology – even in the case of transgenic organisms – the genome on which the modification takes place is either the product of natural evolutionary processes or is the descendent of a product of natural evolutionary processes.

This is not the case in synthetic biology. Synthetic biology does not start with a viable genome and modify it. Synthetic biology starts afresh with bio-bricks possessing known properties. There is no existing genome that undergoes modification. Though the constructed DNA sequences are inserted into single-celled organisms, the idea is not to preserve properties of the existing bacteria with modified behavior. It is to create an entirely new organism. The products in synthetic biology do not borrow any genetic function from genomes produced by the historical evolutionary process. To the contrary, synthetic biology is guided by the idea of leaving evolution behind in order to do a better job of creation with human goals in mind.

There are a number of familiar prudential worries that immediately arise around synthetic biology. Environmentalists should certainly be concerned about the havoc such synthetic organisms might wreck on the natural world. Even synthetic biologists themselves already recognize the worry. The Venter Institute in California states on its website that “[T]he group has long been committed to fully exploring and educating the public about the ethical issues surrounding synthetic life. As such the team is dedicated to developing only synthetic organisms that completely lack the ability to survive outside

the lab."[5] Steve Benner, a synthetic biology pioneer at the University of Florida, tries to create similar reassurance with his claim that "[t]he more different an artificial system is from a natural biological system, the less likely it is to survive in the wild." But in addition to the important prudential arguments, it seems that there is a clear basis for a deontological argument against synthetic biology.

In a famous article against the coupling of nanotechnology with biotechnology in *Wired Magazine* in 2000, Bill Joy, founder of Sun Microsystems came close to articulating the problem. Joy claimed that future bio-nano technologies will cross a fundamental line when they allow the "replicating and evolving processes that have been confined to the natural world…to become realms of human endeavor" (Joy 2000). Joy's worry can be refined to apply precisely to synthetic biology. Artificity is again the problem. But the reason that the artificity in synthetic biology is particularly worrisome is that it is a kind of artificity that departs from the fundamental principle of Darwinian evolution, descent through modification.

Charles Darwin himself, when searching for clues as to how the transmutation of species occurred in nature, spent many hours amongst dog and pigeon breeders admiring what these breeders had created using selective breeding techniques. His comfort level in this company is revealing. Darwin appreciated that when a person modifies an existing genome through selective breeding he or she is doing much the same as what natural selection has been doing continuously for over 3 billion years. In fact, it was because these breeders were doing something so similar to natural selection that Darwin was able to gain important insights that he incorporated into his emerging theory.

[5] See the research page of the Venter Institute's web page (http://www.venterinstitute.org/research).

Since natural selection works by taking an existing viable genome and modifying it incrementally, it seems plausible to accept selective breeding, hybridization, and genetic technologies on the basis that they do largely the same thing. Even late twentieth century molecular biotechnology, including the creation of transgenic organisms, follows this basic pattern. Viable genomes are modified incrementally, with humans in laboratories now playing an integral role in such modifications. Clearly the modifications are not as incremental as they were in the case of pigeon breeding. Many of today's modifications would never have happened through natural or selective breeding. Nevertheless the biotechnology of the late twentieth century might charitably be viewed as morally acceptable because it retains the essence of Darwinism. That is, it takes an existing viable genome and modifies it.

The retention of the essence of Darwinism brings in the relevant moral factor. Because of this Darwinian essence, there remains in place with genetically modified organisms a continuous causal chain between the genome currently being manipulated and the historical evolutionary process. At every point in this chain, there has existed a viable organism. This is true even if the organism being modified is itself the product or selective breeding or transgenic. No product of twentieth century biotechnology lacks this causal connection through a series of viable organisms to the historical evolutionary process. Before synthetic biology, every organism had ancestors connecting it to its historical past.

When a synthetic biologist creates a genome from scratch, by contrast, building organisms *de novo* from bio-bricks, causal continuity with the historical evolutionary process through viable organisms has been severed. With synthetic biology, all trace of

descent from naturally selected ancestors has been replaced. The biotic artifacts created by synthetic biology borrow none of their genetic make-up from viable products of the historical evolutionary process. A genome built from bio-bricks is an artifact in as complete a way as any biological organism can be. This makes it possible to offer a deontological argument that accepts hybridization, selective breeding, and late twentieth century genetic biotechnology but rejects synthetic biology. It does this because it finds synthetic biology creating a more fundamental type of biotic artifact.

The heart of this argument against synthetic biology is consistent with the worries articulated by Keekok Lee but it finds them realized in a different place. Lee argued, correctly it seems to me, that "the supercession of natural evolution" (2003, 190-3) is a serious worry for environmentalists. But the supercession of natural evolution does not occur, as Lee suggested, when humans take a genome created through natural processes and modify it. Nor does it occur when humans take a modified genome and modify *that*. It occurs when humans create new genomes from scratch. In the former cases, there remains in place a continuous causal historical process connecting the latest modification to the 3.6 billion years of the natural evolutionary process. This causal connection remains even when the last few steps in the chain have involved the active manipulation of the genome by humans. Contra Lee, humans do not usurp the historical evolutionary process when they simply modify an existing genome. But in the case of a bacterium with its DNA created through synthetic biology, there is no causal chain of viable organisms connecting it with the historical evolutionary process. As Lee suggested was the problem with molecular nanotechnology, synthetic biologists create biotic kinds *de*

novo. It is this creation of organisms *de novo* that makes synthetic biology different from previous biotechnologies.

VI. An objection briefly considered

Proponents of synthetic biology will likely be unimpressed with this line of argument. They might offer the counter-argument that it is part of human nature to build and create things, many of them from scratch. Why would building and creating biological organisms be any different from building and creating synthetic abiotic objects? Why is it morally significant that the products of synthetic biology depart from the historical evolutionary process even if, allegedly, the products of molecular biotechnology do not? After all, when discussing molecular nanotechnology earlier, I suggested that there is no particular reason to think that creating new kinds of abiotic materials was morally problematic, especially since chemists have been doing so for hundreds of years. Why are things any different with synthetic biology? And what is the moral significance of rupturing the causal chain that connects an organism to the historical evolutionary process?

If this objection is to be successfully answered it probably needs to be answered from within the normative commitments of environmental philosophy itself. *If* you are an environmentalist that puts any normative stock in the idea of "the historical evolutionary process" *then* synthetic biology should be opposed on deontological grounds due to the way it disconnects the biological artifact from this evolutionary history. This really is a supercession of the natural evolutionary process in the way that is different from any previous form of biotechnology. If that natural evolutionary process has

substantial normative significance – and my suggestion above was that it does have normative significance for most non-anthropocentric environmentalists – then these biotic artifacts are morally different from all previous ones. Environmentalists that find some value in the historical evolutionary process should see synthetic biology as morally problematic.

At first this looks like a fairly substantial deflation of the argument since I have limited it to those that hold a particular view in environmental philosophy. Two brief closing thoughts come to mind. First, the intuition that the natural evolutionary process has some role to play in establishing the moral significance of the natural world is, I suspect, a widely held premise amongst environmental thinkers. Both anthropocentrists and non-anthropocentrists make some use of this idea. It has traction beyond simply those that are objectivists about natural value. Because of the widely held nature of this premise, the creation of organisms that have no continuous causal connection to this process is a dramatic development. Second, even if this line of thinking limits the argument in terms of who can use it, it does manage to retain what has always been a pivotal distinction for environmentalists. One of the claims made earlier in this paper was that Aristotle's relatively simple distinction between nature and artifact, though considerably undermined, is not yet redundant. Environmentalists just have to find the appropriate context in which to use it. The key context is the 3.598 billion years of "natural evolutionary history" before the creation of the first artifact. The line of objection to synthetic biology developed here relies on the moral significance of a causal connection to that history. If that significance is denied, many – perhaps the majority – of positions in environmental philosophy may be under threat.

BIBLIOGRAPHY

Aristotle. 1929. Physics, Books I-IV, trans. P. H. Wicksteed and F. M. Cornford (Cambridge, Mass.: Harvard University Press)

Comstock, Gary. 2002. “Ethics and Genetically Modified Foods” in Genetically Modified Foods, eds. M. Ruse and D. Castle (Prometheus: Amherst, NY).

Hargrove, Eugene. 1989. The Foundations of Environmental Ethics (Prentice Hall: Englewood Cliffs, NJ)

Katz, Eric. 1992. “The Call of the Wild," Environmental Ethics 14(1992):265-73

Lee, Keekok. 1999. The Natural and the Artefactual: The Implications of Deep Science and Deep Technology for Environmental Philosophy (Lexington Books: New York)

Lee, Keekok, 2003. Philosophy and Revolutions in Genetics: Deep Science and Deep Technology (Palgrave MacMillan: Basingstoke)

Rolston, Holmes, III. 1988. Environmental Ethics: Duties To and Values in the Natural World (Temple University Press: Philadelphia, PA)

Shiva, Vandana. 1993. Monocultures of the Mind: Biodiversity, Biotechnology and Agriculture (Zed Press, New Delhi).

Shiva, Vandana. 1999. Stolen Harvest: The Hijacking of the Global Food Supply (South End Press, Cambridge, MA)

Vogel, Steven. 2002. "Environmental Philosophy After the End of Nature" Environmental Ethics 24.

Whitesides, George, 2001. "The Once and Future Nanomachine." Scientific American (Sept).