Synthetic Biology: Some Concerns of a Biodiversity Advocate
Remarks on Synthetic Biology to the Presidential Commission on Bioethics

Bryan G. Norton
Distinguished Professor, Philosophy, Science, and Technology
School of Public Policy
Georgia Institute of Technology
September 13, 2010

Executive Summary:

My remarks are intended to begin a discussion, so far at best muted, about the implications of synthetic biology for the future of biodiversity policy and for biodiversity itself. As is inevitable, the emergent field of synthetic biology is creating its own concepts, definitions, and measures. Behind my specific worries, listed below, is a concern that, as the new field develops a conceptual framework and a appropriate to its internal needs, the emergent field may lose its connection to biology, ecology, and its practitioners may lack the conceptual links that encourage them to recognize the importance of natural habitats for wild species. Synthetic life forms are not, and cannot be, a substitute for a living, breathing, evolving species. To the extent that life forms are reduced to collections of "biobricks", without a clear articulation of the importance of *natural* diversity for both instrumental and more moral reasons, synthetic biology may unwittingly become the enemy of biodiversity protection *in situ*.

To begin, I propose for discussion the following statement, on which I invite comment:

1. Synthetic Biology Introduces Life Forms that Are New in an Important Sense.

The new life forms promised by synthetic biology are different even from genetically modified organisms hitherto produced by recombinant DNA methods in that those organisms, such as hybrid corns, have involved the insertion of alternative genetic material into a structure that can live and reproduce, and the insertions themselves were also taken from an organism that can be traced back to a naturally evolved life form. Synthetic biology goes beyond the recombination of genetic material to create new material and life forms with no precedents in the natural world.

Is this an *important* difference?

3 arguments that suggest it is:

1. Unlike naturally occurring species, they have no evolutionary history;
2. Unlike naturally occurring species, they have no ecological history;
3. Synthetic life forms have the potential to confound our traditional taxonomic categories, including the classification of species itself.

2. Advances in Synthetic Biology May Negatively Impact the Social Goal of Protecting Naturally Occurring Biodiversity

A. Will confidence in our ability to create life forms undermine concern for naturally occurring biodiversity?

B. Will synthetic biology's emphasis on parts, wholes, and artificial units of life encourage the inaccurate model of biodiversity protection as maintaining an "inventory" of biological units?

C. How will the creation of new forms of life affect our current understanding of the values that are attributed to wild organisms, species, and ecosystems?

A number of the entries in the briefing book for the September 13-14, 2010 meetings of the Presidential Commission for the Study of Bioethical Issues point out that the practitioners of synthetic biology come from a variety of disciplines, including genetics, engineering, and physiology, as well as biology. The exciting advances in this field have only been possible given the emergence of research groups and professional organizations that incorporate ideas and techniques from many fields. In the process, this diverse group is in the process of developing its own vocabulary and working assumptions and concepts which, in turn, are creating a new field that, while based in biology, has goals and objectives that differ from existing biological studies. As this new field--its assumptions as well as its successes and products--are further developed, it is not surprising that it is creating a conceptual framework that diverges from traditional biological terms and concepts. This is typical of new and developing fields as they create their own identity. Accordingly, the new approaches known as synthetic biology raise important risks and opportunities, requiring public discourse and policy debate regarding the appropriate legal and regulatory framework to govern the new field. What I notice, as a long-term student and advocate of biodiversity and biodiversity policy, is the extent to which this new field is building a vocabulary and perspective that is increasingly independent of traditional biological science. This new vocabulary in some ways parallels—and in other respects clashes with—ideas and policies developed to address threats to biological diversity in the world outside laboratories and factories. In my remarks, I will explore some of the points of connection, and some of the clashes, I see between the evolving perspective and viewpoints of the new field and existing science, advocacy, and policies to protect biodiversity as it appears in the natural world.

I will, first, ask: How new/unprecedented are the results of research and activities of Synthetic Biologists? I will then argue that synthetic biology and its products differ in kind from ongoing activities and resultant products of recombinant DNA technology in at least one sense of importance to our thinking about biodiversity protection. Building on this tentative answer, I then explore three ways in which this difference is important to our understanding of the diversity of life forms. Then, in Part 2 of my remarks, I will explore more broadly some reasons why this biodiversity advocate worries about the long-term effects of successful development and implementation of technologies based in synthetic biology. An important conclusion is that the public discourse about the future of synthetic biology needs to include an ongoing and open discussion with conservation biologists and advocates for policies that protect biological diversity.

1. Synthetic Biology Introduces Life Forms that Are New in an Important Sense.

If one considers the procedures and activities of practitioners of synthetic biology, one might reasonably argue that there's not that much new here, given the rapid advances and applications of recombinant DNA research and associated product development. Synthetic biology, it would seem from this viewpoint, merely pushes an existing knowledge base and emergent technologies into a new area of study with the goal of creating life forms which not only recombine new genes in existing species, but also involve creating new life forms using human-devised building blocks or by radically altering the genetic instructions directing the growth and replication of cells. From the viewpoint of techniques employed, one could make a case that synthetic biology and its procedures and activities represent only an incremental change from activities engaged in by geneticists and product developers for decades.

While not challenging this incremental view of techniques and activities, I nevertheless believe that synthetic biology does involve an important innovation, one that may be important for the ways we think about biodiversity and also for the ways we go about protecting biological resources. In particular, some of the developments, either underway or proposed, seem to me to introduce a product that is in important ways "new under the sun."

The difference-in-kind to which I refer is that synthetic biologists, either have already or eventually will, create new life forms that differ radically from normal biological life forms in that neither the life forms themselves nor their precursor genetic structures have an evolutionary history or an ecological history. While new strains of common species used by humans, such as hybrid corn, are new, involving gene combinations that have not occurred in nature, the genes inserted to create those strains can be traced back to wild ancestors that evolved through competition and natural selection, and the new hybrid maintains the structure of the parent species. If synthetic biologists create life forms with no such lineages, I submit that we will then encounter life forms that have never been challenged by the rigors of ecological competition and evolutionary response that anchor our most basic assumptions about "natural" life forms.

While this premise may prove controversial—and I look forward to discussing of it with people who know a lot more about synthetic biology than I do—I proceed to explain how this premise may have potentially radical empirical implications and conceptual consequences. First, the new life forms have no *evolutionary* history. Understanding naturally occurring species always involves seeing them as emergent from a historical lineage, which allows us to understand the continuities and the genetic innovations that allow species to adapt to changing environments. Biological understanding of a species has hitherto involved careful reconstruction by paleontologists of the slow and gradual changes that lead to adaptive innovation and speciation.

Second, the new life forms will have no *ecological* history; they have never engaged in competition or struggled for niche space, nor have they faced the challenges of responding to changing environmental conditions. Again, the new life forms anticipated by synthetic biologists would exist in an intellectual space that does not include most of the questions biologists ask about naturally occurring species.

Third, while the point may be more conceptual than substantive, such life forms have the potential to confound our traditional ways of talking about species and their role in biodiversity. As Stephen Jay Gould argued, "Species are nature's objective packages."[1] He goes on to argue that, while recognizing that historical changes involved some gradualism in species formation, we can (with only a few exceptions and marginal cases) identify and discriminate species by empirically observing breeding patterns in the wild: a species and its conspecifics can thus be grouped together based on empirical evidence. Gould goes on to argue that this empirical reality behind classifications of

---

[1] Stephen Jay Gould, "What is a Species?" <u>Discover Magazine</u>, 1992. (Reprinted in <u>The Environmental Ethics and Policy Book</u>, 1994. D. VanDeVeer and C. Pierce, Eds. (Belmont, CA: Wadsworth Publishing Company), pp. 473-477.

species implies that biodiversity policy should, whatever else it does, protect species as the most empirically reliable identifier of biological diversity. But what of the new life forms created by synthetic biologists? They have never had to find a mate; they have never suffered from rapidly changing environments, etc. Would we be able to determine whether two organisms are of the same species? Or, do we have living “packages” that confound our usual biological classifications?

This point is mainly conceptual, and it may only affect us in the future, since even among naturally occurring bacteria the criteria for species-hood are somewhat blurry, and its not surprising that species boundaries are fluid in very simple life forms. Creating new and more complex life forms, however, would create biological forms that scramble our usual taxonomic structures, and narrow the questions—about ecological and evolutionary histories of these life forms—that have organized biological thinking since Darwin. In the next section, I will extend these conceptual worries to wonder if synthetic biology and the conceptual innovations it will require may be damaging to efforts to protect naturally occurring biodiversity.

2. Advances in Synthetic Biology May Negatively Impact the Social Goal of Protecting Naturally Occurring Biodiversity.

A. Will confidence in our ability to create life forms undermine concern for naturally occurring biodiversity?

Biodiversity advocates worry that growing confidence in our ability to create new life forms may cause casual supporters of protectionist policies to become complacent, worrying less about protecting naturally occurring species and the processes that support them. We can call this the “shortcuts problem.” One of the most powerful arguments for species and diversity protection stems from the irreversibility of extinction events. In my view, and the views of most conservation biologists, this irreversibility is not challenged by any current or even foreseen abilities to create new life forms. Given the point, made above, that synthesized life forms have no evolutionary or ecological history, it follows that they do not represent possible substitutes for lost species. Loss of a species or extirpation of a subspecies from an area affects many other species and, especially, the ecological and evolutionary patterns that characterize its host ecosystems. Synthetic life forms cannot “replace” a species in natural contexts.

I do not think this point is controversial among practitioners of synthetic biology, who expect the habitat of their new life forms to be a laboratory or an artificial production facility, so this should not be seen as a criticism of them. Nor do I think conservation biologists would even consider accepting such shortcuts to biodiversity protection. My worry, on the other hand, is that policy makers and casual supporters of biodiversity protection among the general public will falsely believe that synthetic biology reduces the risk of irretrievable losses from the natural world. Thus simply stated, this problem may be resoluble mainly by careful and effective communication of the difference between synthetic forms of life and naturally occurring species, but I think that it suggests an urgent need for interdisciplinary scientific and policy discussion in this area.

B. Will synthetic biology's emphasis on parts, wholes, and artificial units of life encourage the inaccurate model of biodiversity protection as maintaining an "inventory" of biological units?

Here, again, it is useful to distinguish between the attitudes and beliefs of professional conservation biologists and biodiversity advocates, on the one hand, and policy makers and the public on the other. Most professionals in the area are well aware of the importance of processes and inter-relationships in natural systems and, when they speak of biodiversity as if it can be tracked by inventorying species and then carefully maintaining the units in the inventory, they are quick to qualify the use of species lists as at best a useful marker, a short-hand for keeping track of how we are doing. [2]

Those who are less involved in the day-to-day work of biodiversity protection, however, may see the growth of synthetic biology, with its conception of life forms as constructed from parts to create new "wholes," as encouraging a static conception of biodiversity as a stockpile of parts, organisms, species, etc. This attitude is dangerous in that it emphasizes elements of nature rather than the underlying structures and processes that allow species to be perpetuated *in situ*. Building a stockpile of new parts, and developing tools that allow creation of more life forms, cannot substitute for protecting species as integrated into a natural habitat any more than zoos can substitute for protection of species in the wild.

Concerns of this type, while mitigated by occasional qualifying clarifications by conservation scientists, are based in the most basic principles of biology and natural history, which recognize the importance of natural processes of evolution and ecology as central to saving biodiversity. Again, it may seem that I make too much of this point about the impact of ideas of parts, wholes, and inventories on policy discourse that extends beyond scientists' viewpoints, but public discourse is important to biodiversity policy. For example, empirical studies of the attitudes of citizens toward biodiversity has shown that members of the general public either do not understand the term "biodiversity" or in some cases have a negative reaction to the term. If, however, they are asked about whether they support efforts to protect "the web of life", they support protectionist goals more strongly. The implication of these results suggest that a lot of work and communication will be necessary to improve public understanding of biological concepts, and it would be helpful if we could move beyond the inventory conceptualization and connect policy proposals to common-sense ideas about nature as a collection of complex processes rather than as a list of elements. [3]

---

[2] See Thomas Lovejoy, "Species Leave the Ark One by One," in The Preservation of Species B. Norton, Ed., (Princeton University Press, Princeton, NJ, 1986)

[3] Ecologists recognize three aspects of total biological diversity: species diversity, within-habitat diversity, and cross-habitat diversity. While total diversity is sometimes represented with species lists, the dynamic aspects of diversity play out in processes within habitats and at the edges of differing habitats. R. H. Whittaker, "Vegetation of the Siskiyou Mountains, Oregon and California," Ecological Monographs 30(1960). Also see B. Norton, Why Preserve Natural Variety? (Princeton University Press, Princeton, NJ), pp. 31f and 58f for further discussion.

One recommendation that seems to me to follow from this brief analysis is that, if practitioners are going to help the public to understand the difference between naturally occurring diversity in ecosystems and the products of synthetic biology, it will be necessary to engage in a comprehensive, cross-disciplinary and public discussion of the meaning of "diversity" in biology. Only when some of these complexities are clarified will it be possible for policy makers and the public to respond intelligently both to the needs of biodiversity protection programs and to the needs and appropriate policies for regulating the progress of synthetic biology.

C. How will the creation of new forms of life affect our current understanding of the values that are today attributed to wild organisms, species, and ecosystems?

As is well known, humans of all cultures make use of natural products and of wild species to increase human welfare and in this sense attribute "instrumental" value to the natural world and its elements. At the same time many humans value nature "noninstrumentally" as well. There is a great deal of disagreement about how to understand noninstrumental valuings of nature, with some environmental ethicists arguing that nature and some of its elements have has *intrinsic* or *inherent* value that does not depend on humans' valuing them, while others would describe this value as religious, spiritual, or aesthetic. Without here trying to define and parse the exact meaning of noninstrumental values, the idea can perhaps be given the intuitive meaning that, just as human individuals can be treated as useful and yet we insist that humans also have a "dignity" or "non-use" value that cannot be reduced to their uses by other humans, nonhuman elements of nature likewise have a dignity and status that lifts them above the role attributed to human artifacts.

I think it can be said with confidence that most citizens value nature in at least the two ways mentioned above. Citizens generally recognize that nature provides us with the raw materials from which we fashion our economy and culture (as instruments of our well-being), and they also attribute some kind of noninstrumental value. These noninstrumental values are explained differently as practitioners of different disciplines use their specific vocabularies to characterized them. They are referred to by economists as non-market, "existence" values, while some environmental ethicists and many citizens believe that nature has a good of its own. But these differences are not material to our current concerns with synthetic biology and this is not the place to adjudicate value theory. My concern is whether the language and culture that animate research and applications of synthetic biology may come to "cheapen" nature, to see life as a program of "biobricks" that are valuable only for the Leggo combinations they can function in.

Will values today placed upon nature and wild species somehow be devalued by the advance of synthetic biology? I'll not predict an answer to that question, even though it is fateful for the future of biodiversity on earth. I would like to close by noting that it is not implausible to claim that a culture that sees life as collections of biobricks might lose its passion for wild nature, and forget its moral value beyond its exchange value. Likewise, I think its not implausible to tell a story of our future culture that sees an over-emphasis on synthetic biology blinding future people to the key role of natural resources and a diverse biotic world in instrumental, economic terms. As I say, this is a concern I can only raise; how it comes out, it seems to me, may be tied back to the point I made in

2B, that our culture needs to have an enlightening discourse, in conjunction with the examination of policies to guide synthetic biology, about the diversity of meanings of “diversity” that currently stifle any common discourse among practitioners of conservation biology, environmental policy, and synthetic biology.

Note:

I have not included the risk of “escape” of synthetically produced organisms, even though this risk might have very direct application to biological resources. One can tell stories of natural ecosystems—not in the too-distant future—ravaged by a runaway synthetic that turns invasive. I recognize the importance of this concern, but I defer to the experts on risk management to discuss this aspect.