The idea of propriety makes an issue of the fittingness of our conduct to our place or circumstances.... We are being measured... by a standard that we did not make and cannot destroy. It is by that standard, and only by that standard, that we know we are in a crisis in our relationship to nature.

—Wendell Berry

I believe one of the reasons our lives are so difficult today is because of the separation from the rest of the natural world that we’ve insisted on having, our insistence on the primacy of human life. Human history, you know, is but one dimension of natural history. It’s not the other way around.

—Barry Lopez

Woody Allen’s film character, the quintessential big city dweller, indoorsman, and nervous meta-physician, remarks somewhere, “I am at two with nature.” By this he means he is not against the natural world per se but does feel apart, anxious, ambivalent, and not at home in it. When he is in nature, he is not of it.

I myself have the same uncomfortable attitude toward biotechnology. I am at two with the awe-inspiring power and accomplishments of science and technology that intrude upon and seek to control life. I would like to be able to say a plague on its house. But that is neither a practicable nor a responsible position to take, thanks precisely to the fact that plagues and other sufferings are real, not metaphorical, and can be eased with a prudent use of biotechnology. It’s the complicated things that we need to think about here.

Being at two with biotechnology requires the hubris (audacity, self-assurance) of a creator and the humility of a creature, while living in a narrow place between power and restraint. The point toward which I gesture in this essay is that to exercise power without restraint is weakness; to master the will to mastery itself is the true mark of humanity. That is the kind of humanity that nature requires of us all, especially now.

REFABRICATING NATURE

In my youth, I lived in the shadow of nuclear physics and nuclear weapons. Everyone did. The prime imperative then was to forbear in the face of a technology that would bring cosmic forces within the atmosphere of the planet, thereby destroying most life on Earth. Now I live under another technological challenge to planetary life posed by genetic engineering and synthetic biology. Everyone does. Biotechnology has a lower profile in the public mind than nuclear weapons. Yet it too forces us to wrestle with unthinkable thoughts. The challenge of our time is not to forbear entirely but to prudently limit a biological technology that would transform much of the evolved life on Earth into an artifact of human will. Today, systems biology and biotechnology have the wherewithal to redesign and reverse-engineer biological systems using techniques of molecular manipulation.

The creator perfects and redefines necessity; the creature creatively adapts to necessity and achieves a modus vivendi with it.

Even as human economies powered by fossil carbon energy are altering the ecosystemic and climatological parameters of life at a planetary scale, two new forms of genomic engineering have arisen in the last few years that mark a watershed in the deliberate reshaping of life at the molecular level. These are “genomic editing” and “gene drives.” The fossil carbon era has shown that humans are capable of refabricating nature—recreating its assembly, resilience, and affordances—on a planetary scale. Gene editing and gene drives will take deliberate refabrication into the cell, the basic unit of life.

Genomic editing uses a protein called CRISPR-Cas9 that can target and alter areas of DNA in
the nucleus of cells. It goes beyond what used to be called “genetic engineering” and is considerably more precise, effective, and economical than previous modes of gene splicing, using recombinant DNA techniques and other means first developed in the 1970s. It may greatly enhance understanding of basic biological mechanisms, and it will open new doors to many practical applications on plants and non-human animals, and even in human medicine as well. In 2018 a Chinese researcher used CRISPR to modify the DNA of two human embryos, which were then implanted and carried to term. Currently in many other countries, including the United States, genetically modified cells are being introduced into patients in hopes of treating genetic disease.

For their part, gene drives extend human fabrication into the intergenerational domain of biological evolution, substituting human intentional selection for natural selection. What would Darwin say about this development? Somehow I doubt that he would approve of human beings in a hurry giving evolution’s tangled bank a buzz cut. Gene drives work by encoding the CRISPR mechanism to alter a particular DNA sequence in the reproductive cells of an organism. In this way, the probability that certain traits will in fact be replicated by offspring and continue to be propagated in subsequent generations can be greatly increased. Thanks to gene drives, inherited traits dominant in a species will not be the result of Mendelian probabilities or environmental adaptation; human drivers and editors will select them. Gene drives are not feasible in human beings or many genomically complex species, although one should never say never. But gene drives will have applications in simpler plants and animals. Proof of concept research with gene drives has recently been published with yeast, fruit flies, and two species of mosquito.

*Homo sapiens* has been probing the secrets of life through the domestication of plants and animals for many thousands of years, but today human beings stand poised to fabricate living entities that neither natural evolution nor human husbandry have ever produced. Thus we stand at a historical moment when we must face the tension between two facets of our humanness.

To a degree of complexity and scale not exhibited in many other resourceful, adaptive species, human beings are both *creators* and *creatures*. The creator perfects and redefines necessity; the creature creatively adapts to necessity and achieves a *modus vivendi* with it. Human beings are both because we do both. We clearly do have the architectonic ability and the hubris to refabricate the world. But our communal, creaturely mode of being human offsets that by relying instead on humility to assist the world in making itself whole again. The heart and mind of the human creature say that we should see ourselves as steadfast members of the biotic community, accepting and accommodating what evolutionary natural selection has bequeathed to us, warts and all. The heart and mind of the human creator say that we should see ourselves as sovereign over life, fashioning enhanced forms of synthetic life and genetically driving evolution in better ways through anthropogenic selection.

In the age of biotechnology and biopower, our creative technological action reveals the bold pride and intelligence of hubris, but not always the balanced wisdom of humility. Humans are in the driver’s seat when it comes to nature but are driving without brakes. A primary question of our time, related to the multiple planetary crises we face, is whether our creaturely inclinations and mentality can rein in our creative quest for perfection and mastery.

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**THE MOLECULAR GAZE**

A large part of the problem is that “technology” is understood as physical and biochemical instrumentality, machinery, and apparatus rather than a mode of technical knowledge containing its own distinctive orientation toward the world.
Technology is a structure of interrelated ways of thinking and acting: ways of thinking about reality, nature, and other people, and cognate ways of interacting with nature and with other people. A technology is a complex of modes of production and relations of production. It is also a structure and a culture of fabrication. It marshals thought and action in the service of power, in the service of refashioning the given in accordance with human will and desire.

The trouble with biotechnology is not limited to risk of accident, unintended consequences, or the concern that biotechnology will be misused by malign agents, although most of the public discussion focuses on these concerns. At a deeper level, however, the problem with biotechnology (or any technology, such as Artificial Intelligence, nanotechnologies, or smart phones) grows out of the suspicion—I would call it an insight—that institutionalized science and technology innovation has a logic and agency of its own. Not to put too fine a point on it, science and technology are not best understood as things we use or abuse, they are, rather, powers that use—or abuse—us. The question of how much and in what ways we should control the natural world is not finally separable from the question of how much and in what ways we should control the human world. A global bioeconomy is being built rapidly; the normative, ethical work of governing it responsibly proceeds slowly.

Technology engages in cultural worldmaking that has natural consequences. As biopower and biotechnology shape our imagination of self and world, they create a worldview within which humanness is defined and what is good about being human is characterized. The perceiving or understanding involved here is active, not passive; it does not simply reflect how individuals think and feel beforehand but constitutes the thoughts it is possible to think and the feelings it is possible for virtually everyone to experience.

Moreover, the specialized terminology and jargon of science tends to colonize ordinary language and to shape common thought. Writing about the context of evolutionary biology, Gillian Beer notes how the explanatory formulations in a theory like natural selection seduce with metaphor the sensibility and imagination of popular culture: “the unused, or uncontrolled element in metaphors such as ‘the struggle for existence’ take on a life of their own.” Another good example of this careless narrative is the title of a recent book on the relationship between humans and mosquitoes, in which the smaller creatures are demonized as “our deadliest predator.”

In sum, biotechnology—and the biopower it confers—operates biologically on many levels and scales, but it also exerts itself culturally by subtly altering both what we think is proper and what we desire. It reconstitutes our relationship to the natural world, but also to our own humanness. Without nature as a measure, respect for evolved forms or natural wholes in life has no moral foothold; everything is seen as decomposable and fungible bits of DNA. This is a new way of seeing life and hence a new way of seeing the relationship between human creativity and nature. Wendell Berry, quoted above, perceived the implications of this and called for “propriety” as I am evoking humility.

The term “biotechnology” was coined in 1943 by the Royal Swedish Academy of Engineering Sciences to designate various ways of pursuing biological solutions to wartime food, energy, and pharmacological shortages. Its first director, Edy Velander, proposed the name bioteknik to describe “applications which arise while one is learning to influence biological processes scientifically and exploit them technologically in an industrially organized activity.” In the domain of bioteknik, nature, or the natural, is not a set point from which deviations can be measured and condemned. The Aristotelian concept of natural form that had for centuries provided a standard of deviation and a point of return is rejected. Historian Nikolas Rose refers to this way of seeing as the “molecular gaze” in his acute book, The Politics of Life Itself:

It is now at the molecular level that human life is understood, at the molecular level that its processes can be anatomized, and at
the molecular level that life can now be engineered... Molecularization strips tissues, proteins, molecules, and drugs of their specific affinities—to a disease, to an organ, to an individual, to a species—and enables them to be regarded, in many respects, as manipulatable and transferable elements or units, which can be delocalized—moved from place to place, from organism to organism, from disease to disease, from person to person.  

The route is short from the molecular gaze on life to the cultural valorization of creative refabrication and improvement as a privileged aspect of humanness. Our views of the true being of nature and life inform our understanding of ethical responsibility and limits. Improvement and progress become our watchwords and our duty. Corporate advertisements have admonished Americans to achieve “Better living through chemistry.” The molecular gaze provides a warrant for this because it strips from living form and metabolism any inherent solidity or depth and thereby removes something that might be called a “preservation necessity” that demands respect for the integrity of what is alive. Having no necessity attached to its evolved form and function leaves life morally available as a field for our manipulation. Today, the rapid growth of technological capability is outstripping the clarity of its goals, effects, and values. We know more about how to alter genomes than we know about what precisely we are doing when we do so, or why we are doing it, aside from the sheer quest to prove that we can. “We are learning to know,” Wendell Berry dryly observes, “precisely the location of our genes, but significant numbers of us don’t know the whereabouts of our children.”

By contrast, the path of rejecting the molecular gaze in favor of a holistic, relational ontology leads toward the valorization of creaturely adaptation and accommodation. I’m not sure which comes first, but I am convinced that how we think and how we live inform one another. In its quest for knowledge, creaturely accommodation does not seek to stand detached from embedded, lived experience within the material world, it embraces its own embeddedness. Natural being with its inherent solidity both enables us and sets limits on what human beings can and should do. Nature calls for respect and accommodation or adjustment, not re-creation and re-engineering. Philosophers Hubert Dreyfus and Charles Taylor express a creaturely perspective in just these terms:

If we return to our most basic, primordial way of being in the world, when we are led to respond to the things in it as affordances, we understand ourselves as at grips with a world that aids us and at the same time sets limits on what we can do. We have to adopt the right stance to it; else we will suffer frustration or worse. The things that are showing up for us as obstacles, supports, facilitators, in short as affordances, have as it were an ontic solidity and depth. They set boundary conditions on our activities. They have what philosophy has come to call their “nature,” which we have to respect and adjust ourselves to.

There is an inconsistency between the positive ecological values that the use of biotechnology is being asked to serve and the mindset that this same biotechnology promulgates within the culture, which undermines the comprehension, even the very articulation, of those ecological values. We should look askance at anything that undermines the perspicacity and humility fitting for a fallible being, or that undermines a willingness (and intelligence) to set limits on our own behavior. We should honor human creativity and innovation but avoid embracing them for their own sakes.

To be sure, the quest to exercise creative sovereignty over the community of life is not an illicit one simply because it sometimes fails or loses its bearings. Eco-modernist or eco-pragmatist thinkers are not wrong to turn to ethically motivated uses of biotechnology in the future as a corrective for the ecological rapacity of the fossil carbon era. This can include the use of gene drives and its successor techniques to improve on evolution by fabricating species with less harmful traits, like becoming resistant to malarial or dengue fever transmission, or with more advantageous ones,
like an increased ability to absorb carbon in the oceans or atmosphere or the enhancement of photosynthesis.

We should honor human creativity and innovation but avoid embracing them for their own sakes.

Yet the bifocal reality of the human creature armed with creative power remains. How can we refabricate nature selectively and judiciously without setting off a more wholesale cultural legitimization of technological mastery? This seems beyond our grasp. Environmental historian Ben Minteer also sees in the genomic engineering impulse an expression of human arrogance and the will to power. He worries that it will reinforce that very attitude just at a time when we need instead to cultivate its opposite: a stronger sense of limits and humility. Genetic modification in the wild, he writes, “is in many ways a refusal to accept our moral and technological limits in nature.... We are a wickedly smart species, and occasionally a heroic and even exceptional one. But we are a species that often becomes mesmerized by its own power.” To this I would only add that the mesmerization in question is not a short trance but a long-lasting trace in the moral imagination.

SOLIDARITY WITH THE MOSQUITO

The tension between the posture of creative design control and creaturely membership in a shared community of diverse, evolved life comes into play quite clearly in debates concerning the release of genetically modified organisms into the wild. Wary of known and unknown unknowns, scientific field research on genetic modification and “enhancement” of domesticated plants and animals has tried to set up and maintain containment measures. Even this has not always been foolproof—stray GM pollen has gone into the wind, GM seeds have fallen by the roadside from passing trucks—for genes, we now know, are remarkably nomadic, agentic, and hard to contain. But gene drive technology opens the ethical Pandora’s box here because their entire point is deliberate environmental release. Their raison d’être is to pick up the evolutionary pace, and once out of the gate the runners cannot be recalled. In the end, the desired effects in the target species’ population may or may not take hold, but that is out of the bioteknik creators’ hands. To paraphrase Tom Lehrer, gene drivers make the rockets go up but don’t take responsibility for where they come down.

There is an inconsistency between the positive ecological values that the use of biotechnology is being asked to serve and the mindset that this same biotechnology promulgates within the culture...

Doubtless, with genetic modification of mosquitoes (to break the life cycle of microorganisms that cause serious human disease—malaria, dengue fever, yellow fever, Zika) or rodents (to control Lyme disease or the ecologically destructive effects of non-native or displaced species), significant personal, social, and ecosystemic benefit can be achieved. So what’s the catch? The downside of hubris and the upside of humility. Natural selection and traditional animal and plant breeding by humans change species, of course, but very slowly, by trial and error. Unfortunately, our neoliberal eye-goggles blind us to the fact that sometimes precaution, with its inefficiency, can be our friend. Other methods to cope with the disease risks that gene drives might address—such as human behavioral change to lessen exposure to insect bites and changes in land use laws and planning to preserve and diversify habitat to reduce human contact with species that transmit zoonotic disease—require more community engagement and present fewer opportunities for monetization. Who was the last CEO to instruct plant managers to slow assembly lines down? How long has it been since those who praise small and slow have been taken seriously by policymakers? By contrast, gene drives are a kind
of unnatural selection that operates rapidly and could make big mistakes.

The stakes are high and if genes are to be driven, there are serious reasons to set limits, to create strict accountability, to use braking systems put in place by prudent public policy and oversight, and to look both ways. Individual mosquitoes are unlikely ever to be seen as important, particularly those who feed on human blood. Males never do, and as a matter of fact, some female mosquitoes don’t either; like *Toxorhynchites brevipalpis*, the drinker of honeydew, they prefer plant nectar. Only a few species within two mosquito Genera, *Aedes* and *Anopheles* (*An gambiae* for malaria), cause trouble. Mosquitoes have lived on Earth for 100 million years, far longer than we have. Their pestiferous behavior influences the behavior of animals in some ways that are functional for the ecosystems they co-inhabit. Without mosquitoes, ecological functioning to which they had contributed would change. And it is not merely the good things mosquitoes do that we don’t see, it’s also the other players in the drama of human illness and suffering. Extirpate the *Ae aegypti* or *An gambiae*, and human health would improve in the short run. But that is a temporary expedient. In the long run, it is the various viruses and malarial parasites of the genus *Plasmodium* that we must reckon with. These microscopic ones are resourceful foes. In the long run, viruses now carried by mosquitoes to humans may come to be carried by something else. Gene drive away every deer, mouse, and tick, and our victory over Lyme disease would be pyrrhic.

In ecology there is almost never only one problem, one cause, or one solution. Life—both metaphorically and biologically—is not that simple. When humans intervene in natural systems, we can never do just one thing. We almost always think we can, and then find out we have triggered other things with unforeseen results.

The use of biotechnology is too powerful and too far-reaching in its consequences to be left up to corporate decisionmakers, the profit motive, and the unregulated free marketplace alone. As democratic citizens, we must rise to the occasion of governing this new technology. We should have a strong public health consciousness, to be sure, but we also should have an ecological conscience. We must be at two with biotechnology. We need to embrace the virtues of prudence, humility, and an abiding interest in the common good of all life.

**CIVIC GOVERNING OF BIOTECHNOLOGY**

Reflections such as these inevitably lead to the annals of ecological governance where we find that it is inextricably tied to the governance of science and technology. In closing, I turn to a few aspects of governance that will set limits, apply brakes, and require accountability in the context of a rapidly emerging global economy of biopower. An international and interdisciplinary field known as responsible research and innovation in science and technology (RRI) is emerging in political science and in science, technology, and society studies. What mix of hubris and humility does RRI governance in the domain of genomic and ecological biotechnology demand?

Precisely how extensively—and in what waystechnology transfer will happen with genomic editing and gene drives remains to be seen. Nonetheless, there are several ethical questions about the responsible governance of that larger system of access and use that need to be anticipated and discussed even at this early stage. Actions taken now still have the chance of influencing the shape of the subsequent commercial roll out of biotechnology and the safeguards and ethical values built into its use.

In general, there are two main approaches to science and technology governance—the “command and control” regime and the “commercial market” regime. A command and control regime is characterized by the fact that responsible innovation is defined by legal authority and professional expertise. In a command and control regime, scientific innovation is directed by agencies and ministries sometimes acting directly through explicit law and regulation, sometimes indirectly through the influence of the governmental funding it provides to universities and technology development companies. A market regime is characterized
by the fact that responsible innovation is handled in a way that socializes the consumption of an innovative technology but privatizes ownership of its production. In it, innovations are produced and distributed through market mechanisms based on commercial property rights and patents. In this arrangement the role of any single control agent, whether individual or collective, is greatly reduced. Market governance reflects and is made possible by the collective and institutional nature of scientific and technological innovation.

I do not think expert command and control governance will suffice for biotechnology due to the characteristics of the technology itself, such as the relative ease and affordability of its manufacture, the decentralized and dispersed conditions of its environmental deployment, and the international, cross-border complexities of its command and control requirements. As a teenager I had a simple chemistry set in the basement and could create a small piece of synthetic rubber in a beaker; within a decade my young grandson will have genome editing equipment and the requisite inexpensive chemicals at his disposal, if he is so inclined.

Command and control and market governance of technology are too strongly institutionalized within developed nation states to be supplanted by civic deliberative governance, but they can be supplemented by it to good effect. As people begin to link biotechnology, health, and ecology, it becomes more apparent that the new biotechnology can hold both exciting benefits and sobering harms for some of the most serious existential challenges of our time. This may create what might be called a deliberative democratic opening in our politics, probably at the local level first but eventually at all levels.

To walk through that opening, to take advantage of this opportunity in biotechnology governance, we will need to recognize that the scientific enterprise itself, as well as its public governance, is a particular kind of social ecology made up of individuals and institutions that make a technology possible through their financial resources, expertise, and normative acceptance, often in the form of consumer demand.26

Moreover, biotechnology governance will require a more ecological and relational understanding of the virtues and practices of citizenship, for it is ultimately citizenship that provides the overarching orientation toward the common good binding science, commercial stakeholders, and private beneficiaries of the extended human mastery that the technology provides. The key to such civic activation is transformational leadership voices articulated in new forums and emerging from the crucible of social movements to be articulated in new forums, untroubled except by the force of the better argument. If such a discursive democratic citizenship could be unleashed—as it has been several times in American history—it would hammer out the terms of a new social contract between creator and creature that would be at two with biotechnology and at one with nature.

A deliberative democratic opening exists because, at least in the developed democracies of the world, governance is not completely professionalized and formalized, although the public administration of the state is clearly one important dimension of it. Civic governance creates roles and forums for many...
parties and organizations from the civil society, the private sector, and the various expert groups who have experience and expertise in the molecular science behind biotechnology and the ecological systems it will be used to modify. Civic governance also involves a dynamic of evaluation and legitimation, beyond technical scientific validation and economic return on investment.27 This necessary work of evaluation and legitimation will draw in citizens who are engaged, informed, and motivated sufficiently to contribute to technology governance if they are given the appropriate opportunities and forums for doing so.28 The question is what kind of conversation should we have to determine the terms and scope of the ethical permission society gives for the use of biotechnology and biopower?29

Finally, it is not simply passive engagement or being instructed by experts, but active deliberative contestation that is the goal. Precisely because there is so much predictive uncertainty concerning risks and benefits at the frontiers of biotechnology, many voices must be heard and many value concepts and perspectives must be persuasively and capably argued for, not simply asserted. Also the setting in which democratic deliberation takes place must be conducive to active civic learning.30 The reason to call for public engagement is not simply to mollify and reassure the public that the technology is in good hands. Rather, it is to educate and empower citizens to gain an understanding of the biotechnology applications under consideration that is substantive and critical enough to express evaluative standards, if not to work out more concrete policy regulations. This is no different from what is needed in discussions of environmental policy, and in both cases, it has been and can be achieved in inclusive ways. Ecological democratic citizens must also be historically and ethically informed citizens of a technological society. Not science per se, but the social, legal, and ethical implications of science and technology are the focal point of citizen conversation and debate in a regime of civic RRI governance.

FELLOW CREATURES, FELLOW CITIZENS

In a recent interview, naturalist and author Barry Lopez touched upon one important facet of the practice of ecological relationality and citizenship to which I am appealing. “Whenever I speak in public,” Lopez said, “I begin by stipulating, with a modulated voice, that things are way worse than we imagine.” He continued:

And then the second part of the talk is an evocation of the healing that is necessary and possible, a gradual elevation of the human spirit. It’s about the mobilization that is needed and which is within our reach. Then people know you’ve spoken truthfully, and you have evoked in each person a desire to help, to take care of their families, to have self-regard.31

Are we creators or creatures? Are we beings in control of the world, or beings who prosper by accommodating themselves to webs of symbiotic interdependencies? The interplay of perfecting and accommodating is not unique to human beings—perhaps it characterizes all forms of life on Earth—but with humans these modes of being are distinctive, and our technology greatly expands their scale and effects. Are we creators or creatures, and if both, how can we achieve the balance between them that might be called humility? That at last might be accurately called humanity.

ACKNOWLEDGEMENTS

Many of the ideas discussed in this essay have benefited greatly from conversations with numerous participants in a project on “How Should the Public Learn?—Reconstructing Common Purpose and Civic Innovation for a Democracy in Crisis” now underway at The Hastings Center, with support from the John S. and James L. Knight Foundation.

NOTES


16. Berry, Life is a Miracle, 33.


24. This is a very general typology, but it applies to science governance and policy, as René von Schomberg has recently shown, and it brings out some viewpoints not always explicitly discussed in ethical discussions of biotechnology. See R. von Schomberg, “A Vision of Responsible Innovation,” in R. Owen, J. Bessant, and M. Heintz, eds. Responsible Innovation: Managing the Responsible Emergence of Science and Innovation in Society (London: John Wiley, 2013), 51-74.


