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Urgent Memo to Biotech Pioneers: Life Is More Than a DNA Sequence

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Amory Lovins is chief scientist at Rocky Mountain Institute (www.rmi.org), which he cofounded in 1982. In 2009, Time named him one of the world's 100 most influential people; Foreign Policy, one of the 100 top global thinkers. Parts of this article are adapted from a new article in praise of a colleague. Amory Lovins also wrote this piece in response to another WorldPost piece, "A New Phase Of Evolution" by Craig Venter.

Craig Venter and I share a deep concern about issues like climate change, a dedication to getting off fossil fuels, and a strong suspicion that the universe is so big and old that it's probably teeming with life. But the search for intelligent life on Earth continues. When I read Craig's remarks like:

We're dealing with the design of organisms based on the functions we want. This is something that would never occur on its own in nature. And we can speed up the glacial [evolutionary] process that would occur in nature by orders of magnitude...[, theoretically giving us] control over biological design. We can write DNA software, boot it up to a converter, and create unlimited variations on biological life.

I'm afraid Craig might not be joking or speaking metaphorically. Rather, I fear that he really might not understand the differences between digital computer code and genomics.

To be sure, his team's pioneering work decoding the human genome was a great technical achievement, commercially but not historically devalued by its turning out to be a costly version of the New York City telephone directory, telling you who lives where and has what phone number, but not giving you the foggiest idea who they are, what they do, and especially how their myriad complex interrelationships form a functioning society.

Let me also acknowledge that it could be very useful to make flu vaccines faster -- though probably less useful than rebuilding, sustaining, and improving the immune competence of the general population, and correcting the dangerous proximity of poultry, pigs, and people in Asian cities that makes them an unparalleled "flu factory."

Furthermore, it is impressive -- not a mere parlor trick -- to "teleport DNA" by sequencing it, transmitting the sequence digitally, and re-embodying it in new DNA molecules. But that's utterly different than understanding what life is and how it works. That understanding has so far eluded Craig and all the rest of us, and shows every sign of continuing to exceed our grasp for a long time.

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So I really hope his creations never escape, and that when they do, his "kill switches" and "chemical dependency" will reliably stop them from spreading their alien sequences to actual life or from adapting to survive and multiply. What humans have learned so far about genomics is only a tiny step toward understanding the life process. Meanwhile, our ignorance is not bliss and can be dangerous.

A CAUTIONARY LESSON FROM BOTANY

This is nowhere more clearly illustrated than by the failure of "genetic design" -- previously called (equally inaccurately) "genetic engineering" -- in plants, which are generally simpler than animals. In August 1999, I coauthored an essay for the *St. Louis Post-Dispatch*, excerpted below, as the premier meeting of the world's botanists convened there:

....Plants, shaped into incredible diversity by 3.8 billion years of evolution, make possible all life, underpin every ecosystem, and are resilient against almost any threat -- except human destructiveness. From botany came the genetics of Lamarck and Mendel, formalizing the patient plant-breeding that's created 10,000 years of agriculture.

Now, however, in the name of feeding a growing human population, the process of biological evolution is being transformed. A St. Louis firm is practicing a completely different kind of botany which, in the Cartesian tradition of reducing complex

wholes to simple parts, strives to alter isolated genes while disregarding the interactive totality of ecosystems. Seeking what Sir Francis Bacon called "the enlarging of the bounds of Human Empire, to the effecting of all things possible," its ambition is to replace nature's wisdom with people's cleverness; to treat nature not as model and mentor but as a set of limits to be evaded when inconvenient -- not to study nature but to restructure it.

As biophysicist Donella Meadows notes, the new botany aims to align the development of plants not with their evolutionary success but with their economic success: survival not of the fittest but of the fattest, those best able to profit from wide sales of monopolized products. (High-yield, open-pollinated seeds abound; the new crops were created not because they're productive but because they're patentable.) Their economic value is mainly oriented not toward helping subsistence farmers to feed themselves but toward feeding more livestock for the already overfed rich.

Most worryingly, the transformation of plant genetics is being accelerated from the measured pace of biological evolution to the speed of next quarter's earnings report. Such haste makes it impossible to foresee and forestall: unintended consequences appear only later, when they may not be fixable, because novel life forms aren't recallable.

In nature, all experiments are rigorously tested over eons. Single mutations venture into an unforgiving ecosystem and test their mettle. Whatever doesn't work gets recalled by the Manufacturer. What is alive today is what worked; only successes yield progeny. But in the brave new world of artifice, organisms are briefly tested by their creators in laboratory and field, then mass-marketed worldwide.

Traditional agronomy transfers genes between plants whose kinship lets them interbreed. The new botany mechanically transfers genes between organisms that can never mate naturally: an antifreeze gene from a fish (Arctic flounder) rides a virus host to become part of a potato or a strawberry. Such patchwork, done by people who've seldom studied evolutionary biology and ecology, uses so-called "genetic engineering"-- a double misnomer. It moves genes but is not about genetics. "Engineering" implies understanding of the causal mechanisms that link actions to effects, but nobody understands the mechanisms by which genes, interacting with each other and the environment, express traits. Transgenic manipulation inserts foreign genes into random locations in a plant's DNA to see what happens. That's not engineering; it's the industrialization of life by people with a narrow understanding of it.

The results, too, are more worrisome than those of mere mechanical tinkering, because unlike mechanical contrivances, genetically-modified organisms reproduce, genes spread, and mistakes literally take on a life of their own, extending like Africanized bees. Herbicide-resistance genes may escape to make "superweeds." Insecticide-making genes may kill beyond their intended targets. Both of these problems have already occurred; their ecological effects are not yet known.

Among other recent unpleasant surprises, spliced genes seem unusually likely to spread to other organisms. Canola [rapeseed] pollen can waft spliced genes more than a mile, and common crops can rather rapidly swap genes with weeds. Gene-spliced Bt insecticide in corn pollen kills monarch butterflies; that insecticide, unlike its natural forbear, can build up in soil; and corn borers' resistance to it is apparently a dominant trait -- so planned anti-resistance procedures won't work.

It could get worse. Division into species seems to be nature's way of keeping pathogens in a box where they behave properly (they learn that it's a bad strategy to kill your host). Transgenics may let pathogens vault the species barrier and enter new realms where they have no idea how to behave. It's so hard to eradicate unwanted wild genetic material that we've intentionally done it only once -- with the smallpox virus.

Since evolution is a fundamental process, it must occur at every scale at which it's physically possible, down to and including the nanoecosystem of the genome. Shotgunning alien genes into the genome is thus like introducing exotic species into an ecosystem. (Such invasives are among the top threats to global biodiversity today.) It's unwise to assume, as "genetic engineers" generally do, that 90 plus percent of the genome is "garbage" or "junk" because they don't know its function. That mysterious, messy, ancient stuff is the context that influences how genes express traits. It's the genetic version of biodiversity, which in larger ecosystems is the source of resilience and endurance.

Unfortunately, nearly 15 years later, our 1999 article looks all too prophetic. The genome turned out to be unimaginably complex, combinatorial (one gene doesn't map deterministically to one trait), interactive (epigenetically influenced by environmental conditions to express different genes in the phenotype), fluid (prone to genomic shifts, sometimes generations later, in response to inserted transgenes), and, as I'd surmised, influenced by the ineffably complex context of the "genomic ecosystem."

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With a tenth of the planet's croplands now intensively planted to GMO crops, the emergent environmental side effects I noted are now widespread and serious. By 2013, 24 species of herbicide-resistant superweeds variously infested 25 million hectares in the U.S.A. alone. (In response, the industry promotes new herbicide-resistant GMO crops that will breed new resistances, further exacerbating the already-acute weed crisis.) Pests, too, are rapidly becoming resistant to GMO crops' toxins, and secondary pests are emerging as feared, especially in China and India. Non-target organisms may be suffering, too. From failing honeybee hives to the 2013 collapse of monarch butterfly populations, GMO crops are part of the pattern of stressors. GMO maize and soya in the U.S., for example, are now very largely grown with herbicides that kill the Monarch's vital milkweed food.

Unapproved GMO crops continue to escape into fields and into world trade, disrupting grain markets. Efforts to trace and segregate GMO genetic contamination burden traders in agricultural commodities. By 2004, most U.S. corn, soy, and canola

seeds were contaminated with genetically altered DNA.

Yet despite its huge power and influence, the GMO crop business is faltering. Hints in 1999 that its benefits were insubstantial are now backed by solid evidence. The Union of Concerned Scientists has documented how GMO crops have not significantly increased actual U.S. crop yields (but decreased some, especially when stacking multiple traits); have markedly raised the net use of agrichemicals they were supposed to replace, including older and more dangerous kinds; have probably decreased biodiversity; and have proven two orders of magnitude costlier and manyfold less successful than traditional crop breeding in raising yield, fertilizer uptake, and resistance to pests and drought.

OUR SELF-ENDANGERED SPECIES

Does Craig really understand all this? I can't tell. Just when a suitably cautionary remark makes me think maybe he gets the difference between DNA sequencing and the immensely more complex mysteries of life, another slick metaphor from the digital world revives my concern. That's why I find him both smart and scary -- and why I'm unsure whether his work will help reverse or reinforce our status as the first self-endangered species.