ORGANISMS, MODIFIED, GENETICALLY

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GMOs. Genetically Modified Organisms. They conjure the specter of "Frankenfoods." Monstrous creations reflecting human hubris. Violations of nature. And their very unnaturalness alone seems reason to reject the whole technology.

But one may challenge this common image, this month's Sacred Bovine: that GMOs cross some new threshold, dramatically changing how humans relate to nature. Or even that such a view can properly inform how we assess the value or risks of GMOs. Rather, biologically, GMOs are modest variants. As I will elaborate, "conventional" corn is probably more deeply shaped by human intervention than any addition of, say, a single *Bt* gene for a pesticide-resistant protein. Many crops promoted as "natural" alternatives are themselves dramatically modified genetically, like the cats and dogs we enjoy as pets. And *this* perspective – the context of GMOs – should inform views on policy. Without resolving the question of ultimate risks, we should at least recognize and dismiss as irrelevant the claim that GMOs are "unnatural."

Modifying Organisms

While criticisms of GMOs vary, one recurrent theme is the assertion – or the implicit assumption – that they are inherently unnatural. For example, one student commented on genetically modified salmon:

> Even though it definitely has many economic benefits, I think that shaping the way in which other organisms grow and live is not something that we as humans should be taking into our own hands. (Clark, 2014)

As rendered recently for young readers, a cartoon princess of the Guardian Princess Alliance scolds a grower of GMOs: "These fruits and vegetables are not natural" (Guilhem, 2013). Many seem to believe that for humans to alter something living is to thereby taint it. Organisms should remain "pure" or unsullied. Nature seems to exhibit its own self-justified purpose, or teleology, not to be disrupted.

What does this mean for all the other ways that humans modify organisms from their "natural" state? For example, we adorn our skin with tattoos and pierce various body parts. In certain cultures, at certain times, we have bound feet and elongated skulls. We may reconstruct our bodies "cosmetically" to suit our tastes, perhaps dissatisfied with what "nature" has provided. Indeed, most consider the creation of a smile where there was once a cleft lip a gift.

We also fill teeth with metal amalgams and high-tech ceramics, and reshape the bony orthodontic structure of mouths. We transfuse blood. We replace body parts – transplanting kidneys, hearts, livers, corneas, bone marrow. In some cases, we install human-made body parts instead: hips, knees, pacemakers, stents. More inorganic plastic, metal, and ceramics.

Nor do we limit ourselves to macroscopic physical changes. We inject synthetic hormones and immune suppressors. We ingest antibiotics. We deploy a large repertoire of chemicals that alter neural function: stimulants and depressants, pain relievers, behavior-modifying medications, and psychotropic drugs just for recreation. Perhaps these ways of modifying organisms are so familiar now that we fail to recognize them as human interventions. Or we may rationalize that, because humans themselves evolved, these modifications are expressions of nature, too: of nature beyond nature.

Yes, genetically engineered organisms are modified. But they are modest "DNA transplants." Results of molecular surgery. Given the scale of entire genomes, at tens of thousands of genes, how significant are they? While some modifications yield measurable economic consequences, organically they seem quite narrow in scope. In other contexts, would we even notice the addition of one or two genes among so many?

Modified Genetically

For many, of course, the concern is not modifying nature per se, but specifically modifying *genes*. Genetic technology seems to threaten the integrity of a species. The very label "transgenic" may conjure images of fearsome hybrids, like the monsters of mythology: harpies, sphinxes, satyrs, manticores, and chimeras. One student asked rhetorically, "Are the [GM] crops still the same as before?" But genes are not identity (*Sacred Bovines*, April 2005). In this case, a fear of genetic change reflects beliefs in biological essentialism – a vague conviction that species have a purpose just as they are now, apart from the perpetual flux of evolution.

Again, are we blinded to the familiar? We are surrounded by genetically modified organisms. For example, household dogs. Shepherds to shitsus, dachshunds to dalmatians to dobermans, bulldogs to bull terriers, they are all engineered variants of wolf-like ancestors, domesticated around 15,000 years ago. Since then, humans have generated specific genetic types through selective breeding. While dogs differ from wolves genetically by only about 1%, their diversity illustrates how effectively humans have already modified organisms – genetically.

The same applies, of course, to domestic cats. And domesticated cattle. Chickens. Pigs. Rabbits. Sheep. Goats. The variants of humanly engineered pigeons, from carrier to tumbler to pouter to fantail to capuchin, were certainly well known to Darwin, who commented on them in describing the powerful role of human selection in the first chapter of the *Origin of Species*. Humans have been modifying animals genetically for millennia, including many species that now contribute to our diet.

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Domesticated species notably include food crops as well. Kale, broccoli, cabbage, cauliflower, Brussels sprouts, and kohlrabi are all variants of one species, due to human intervention. Bread wheat is a hexaploid hybrid of three wild species that humans developed about 10,000 years ago. Corn (maize) was developed from wild teosinte around the same time. Many of the historic genetic changes have now been identified, including genes for a softer kernel covering and for less branching in stem growth. There have also been genetic modifications to the "types and amounts of starch production; ability to grow in different climates and types of soil; length and number of kernel rows; kernel size, shape, and color; and resistance to pests" (Genetic Science Learning Center, 2014). "Conventional" corn is itself greatly modified genetically.

Why, then, is so much attention given to crops modified by a single gene – for example, the *Bt* gene? Humans merely moved the gene from a non-engineered bacterium, which had been applied externally as a pesticide, to the cells inside corn plants, where production and exposure of the *Bt* protein could be more circumscribed. In a historical context, the genetic modifications opened by molecular techniques are narrowly focused and relatively modest. Imagine how historical awareness might benefit a student who noted (not atypically): "I personally feel like the genes of organisms, especially those we consume, should not be tampered with" (Clark, 2014). Views of GMOs could well be informed by a deeper understanding of the role of humans in the genetic history of "conventional" crops.

The popular impression is also that scientists have the "unnatural" power to leverage any genetic modification and create any monster imaginable. Few reflect on the physiological integrity of any change. Not all hybrids are viable. Hybridization and horizontal genetic transfer certainly occur far more widely in nature than scientists earlier thought. (Ironically, nature itself seems to have violated what we once considered "natural" patterns!) Still, not every combination is developmentally stable. Nature still seems to limit what genetic changes are possible.

When new technologies are introduced, initial caution generally seems warranted. Yet genetic modification of organisms began decades ago, with microorganisms. Indeed, engineering bacteria to produce insulin, human growth hormone, interferon, various pharmaceuticals, and other products now seems almost commonplace. The basic gene-splicing methods are hardly new. Fuller awareness of this history of biology might also inform views on whether we are now altering nature in some way that is more "unnatural" than before.

Another expressed concern about GMOs is the possibility of "new" allergens. This potential risk, too, seems based on the image of GMOs as "unnatural," or inherently outside the norm. Yet allergens exist in all kinds of foods, not just GMOs – nuts, milk, wheat, eggs, and so on. GMOs are not new in this regard, either. (Indeed, governmental safeguards against such allergens in foods already exist.) The novelty is overstated.

Ultimately, impressions that GMOs are genetically "unnatural" seem to foster all kinds of misleading perceptions, including about what risks may be relevant or significant. We seem to owe ourselves some reflection on genetic essentialism and "naturalness."

○ The Science of "Unnaturalness"

Science, it may seem, can solve the problem by describing objectively what is "natural" and what is not. Indeed, through observations and experiment, science can document what *is* or *can be* the case. Yet "natural" has a second, quite different meaning when discussing GMOs: namely, what *was intended* or *ought to be* the case. This requires a different kind of justification, based on values or assumptions about purpose. So, to contend that something is "unnatural," or aberrant, *and thus also* wrong *morally*, goes well beyond what a scientist could validate. Ethical or teleological arguments differ from the epistemic arguments of science. The two types of "natural" claims are thus not interchangeable. Science is limited in what it can say about the "naturalness" of GMOs.

Still, science can help us reflect on the very notion of "naturalness," psychologically. Images of purposeful "nature" seem easy to come by. Humans tend to project their perspectives onto the world, conflating their personal interpretations with the way nature actually functions. They tend to assume that others will see it their way, too. The concept of "unnatural" thus seems to be based on an unspecifiable (but apparently "obvious") personal intuition. The vagueness certainly makes public discourse problematic. Views of "naturalness" also tend to become quite potent cognitively.

Emotions and attitudes can strongly shape an individual's "science-based" views of GMOs, as with other topics (Hallinan, 2009; Lehrer, 2009). Our minds readily cherry-pick scientific perspectives to accord with prior beliefs or emotions. Thus, passionate advocates may accept flawed research uncritically. They may continue to cite outdated, discredited studies. They may discount counterevidence. Yet they may well still perceive their position as thoroughly scientific.

The view of GMOs as "unnatural" or disvalued also contributes to a suite of scientific misconceptions. For example, many regard "natural" foods as inherently *better*, and *thus also* more nutritious. Even when genetic modifications do not involve nutrients, and without any scientific study, GMOs are presumed to be less healthy. GMOs also seem less viable or less able to reproduce, because they are less "authentic." At the same time, GMOs can apparently grow out of control, overtake other plants, even whole ecosystems, like non-native or "invasive" species. The role of values is also indicated in the assumption that GMOs are able to "infect" other systems with their unnaturalness. (In the same way, many infer that irradiated foods exhibit radioactivity themselves.) One student blogged, "If the genes in the salmon are genetically modified, who knows what it will do to your genes"? (Clark, 2014). Such a claim does not seem to be based on scientific understanding of a possible mechanism. Nor on evidence that other genes can produce such ill effects. Only on vague negative impressions. Students could, of course, expose all these mistakes on their own through a GMO-mythbusting activity. But the deeper question (from a cognitive perspective) is "Why do such myths emerge at all?" Here, these misconceptions can all be traced to a common assumption: that GMOs are "unnatural." Informal reasoning trumps science and evidence. As a result, arguments based on scientific evidence rarely penetrate these perspectives.

To address these types of errors, therefore, one must shift to another, more fundamental cognitive level. One must understand how perceptions of GMO "unnaturalness" originate psychologically. Generally, what we deem "natural" is "what we find more familiar, while what we consider unnatural tends to be more novel – perceptually and experientially unfamiliar – and complex, meaning that more cognitive effort is required to understand it" (Konnikova, 2013). In practical terms, then, "unnatural" means that GMOs are strange and hard to understand. A situation ripe for feelings of insecurity and fear. In this case, implicit teleology and genetic essentialism, discussed above, also seem to contribute. For scientific evidence about GMOs to have standing or persuasive merit, then, one may first need to engage the foundational views about "unnaturalness" and what they mean.

Consider the recent challenge of one county council member in Hawaii, faced with a proposed ban on GMOs there. The community overwhelmingly supported a ban. But local scientists and farmers did not. Taking his charge seriously, he tried to investigate the various claims. He had to learn some basic biology. He had to assess the credibility and expertise of his sources. It took time. But thoroughness helped him sort the quick rhetoric from more complete and reliable reasoning. He gradually distinguished the emotional hyperbole from the mundane but more systematic evidence. His eventual decision was well informed, although not politically popular. His story, recounted by Amy Harmon (2014) for *The New York Times*, can surely stimulate class discussion. Why do we believe what we believe about GMOs? What is the role of science? How do emotions and informal thinking shape our impressions of that information? And how do we effectively identify and manage the different sources of our thoughts?

Are GMOs "unnatural"? Who says so? In what context? Based on what background examples? One might even ask whether farming itself, as practiced through intensive monoculture, is itself "natural" or beneficial (Diamond, 1987). Such an analysis, along with the other broad biological perspectives presented here, might help contextualize and inform the often contentious issue of GMOs. Can we accept the risk that, through critical reflection, we might develop a fuller and possibly transformative understanding of Organisms, Modified, Genetically? OMG.

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