by
Sheldon Krimsky
Illustrations
Bernd Bexte

Revolution or Evolution

Does biotechnology contribute something unique or is it adding just an incremental albeit important step in the evolution of species? We can't expect a single answer. At least in one respect biotechnology is revolutionary: Genetic Engineering is capable of transferring genes from one organism to another one, of crossing barriers between species. The concept of species as protected gene pools isn't absolute, however

Once upon a time there was Utopia: Francis Bacon dreamt of designer plants and outlined an entirely new concept of science and technology

In 1622 the British scientist and philosopher Francis Bacon wrote a utopian essay titled "The New Atlantis" in which he described a period in scientific and technological development when all biological forms would serve as the raw materials for the refashioning of a new biota. He prophesied designer plants that would bloom when we wanted them, agricultural crops with new tastes, and plants that would produce more quickly or show greater fecundity than their natural kinds.

Since the discovery of recombinant DNA technology in 1973, Bacon's fanciful vision of a world of designer crops and animals has become a reality. Just as iron ore, silicon, and coal were the basic ingredients of the industrial revolution, genes have become the substrate for the manufacture of living things. The legal and political systems are adapting to the bio-industrial revolution through the support of global markets and monopolistic control of biogenetic raw materials (germ plasm) for developing transgenic plants and animals. Most industrial countries have accepted patenting of life forms and genetic sequences. Few, if any, have considered the morality of establishing intellectual property protection for germ plasm.

These changes have been accompanied by a great transformation in our belief structure about the nature and role of life on the planet. First, there was the pre-Darwinian idea that each life form was unique and disconnected from each other. Then Charles Darwin introduced the concept of the tree of life in which living forms were connected genealogically and could even be traced to a single-celled organism. Nonetheless, there is reproductive isolation (only animals of similar types could procreate) of distinct and biologically separate classes of living forms. The distinctiveness of biological forms was challenged when the genetic code was discovered. It was learned that all life did not simply evolve from a common protoplasm, but shared the same genetic architecture – both the structure (the double helix) and the fundamental units (codons and amino acids) were universal. Even as the phenotypic variation of living things seemed so great, there were common fundamental units comprising their inner structure.

The discovery of the fungibility of genes forces us to make the next frame shift in our concept of life. We can no longer accept uncritically the aphorism that "like begets like." It cannot be said that a pig's snout is uniquely of a pig and that there is something we call "pigness" that is trapped in the evolutionary construct of the pig family of animals. These so-called species demarcations have been transcended by the discovery that genes can be shifted from organism to organism and with these shifts in genes the phenotypic properties of living forms on the planet can be rearranged as Bacon had foreseen. Scientific artifice has become an important potential factor in the evolution of species. If we view time as one of the features that distinguishes evolutionary change from revolutionary change, then humans through scientific advance have brought about the revolution of evolution. The human intellect has turned the unpredictability of the evolution of new species into a rational and highly predictive process. It may not yet affect the vast amount of natural species that inhabit the earth unless we follow Bacon's plan and begin respeciating the planet according to human design. Also, the precision of genetic engineering, while vastly improving the human-directedness of speciation, is not the first technological tool to achieve that end. As Daniel Dennett has noted: "some features of the natural world – the short legs of dachshunds and Black Angus beef cattle, the thick skins of tomatoes – are the products of artificial selection, in which the goal of the process and the rationale of the design aimed for ... (were) in the minds of the breeders who did the selecting." [1]

The frame shift in our ideas about biological life prompted by the scientific discoveries in genetics and their technological applications has come into conflict with our cultural and political ideas about the living world. I shall discuss three such ideas in this essay: species barriers, emerging risks, and natural foods. In each case we shall ask: Does or will biotechnology contribute something unique and revolutionary or are we adding an incremental step in the evolution of species? The symbolic meanings of these concepts has shaped the public discourse about value, ethics and the social need of transgenic plants or other innovations derived from biotechnology.

Can we cross species barriers?

The concept of species as a "protected gene pool" is not absolute but it functions quite well for multicellular organisms. According to evolutionary biologist Ernst Mayr "the reproductive isolation of a species is a device that guards against the breaking up of its well - integrated co-adapted gene system." [2] During the early years of what has been aptly called "the gene-splicing wars" some of the molecular geneticists, armed with the bravado of moonwalkers or the pride of aeronautical pioneers whose flying machines broke the sound barrier, spoke enthusiastically of applying genetic technology to cross species barriers. Little more than 100 years after chemists learned how to create synthetic molecules and thirty years after physicists split the atom, biologists had taken their field to a comparable place. The early 1970s was the dawn of their "atomic age." The concept of breaching "species barriers" carried two messages, one to the investors who could imagine a cornucopia of new products and one to the general public who had no difficulty imagining the unleashing of an unknown and potentially frightening power. One of the fledgling bioengineering firms, the Cetus Corporation, described the new technology in its company brochure distributed in the mid-1970s:

„The significance of this power cannot be exaggerated. Perhaps the most important breakthrough has been the capability to transfer genes form one species to another. Classically, the definition of a "species" has been that an organism in such a group could not breed (i.e., exchange genetic material) with a member of another group. Nature, through evolution, has created barriers to the exchange of genes between species. Within a species, breeding for improvement is possible and has long been practiced. However, it is not possible to create an animal with the combined characteristics of a dog and a

At the beginning of time there was the big bang: On the tiny planet called Earth amoebae appeared, later insects, plants,

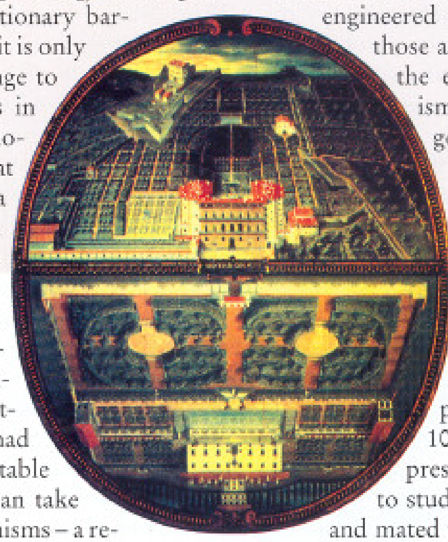
mammals. Mankind crosses many borders: We can form theories about the universe and we can alter the genetic content of tomatoes

Do exist specific hazards in the use of genetic engineering? No one doubts that there are risks. But we must not forget that conventional breeding techniques can produce pretty hazardous results either. Maybe it is but a matter of time: Men can accelerate the chances of a risk event taking place

At the beginning of the modern age there was borderless optimism: Sophisticated courtiers in Italy wanted to model forests and fields for their pleasure. The sciences began to lead mankind on the thorny road out of the dark into the Enlightenment

cat by mating them. These species barriers have so long been accepted as logical and almost absolute, that it is only within the past months that scientists have seriously contemplated the ramifications of breaking these species barriers."[3]

No sooner had scientists announced the conquest of species barriers, than other biologists began to dispute the very existence of such evolutionary barriers. One argument claimed that it is only a matter of time for gene exchange to take place across any organisms in nature. The late Harvard bacteriologist Bernard Davis conjectured that since it was known that bacteria can recombine with free DNA from other prokaryotic species, it is reasonable to assume that they must take up eukaryotic DNA as well. During the peak of the political debates in the 1970s, two scientists published a paper demonstrating precisely what Davis had predicted, namely that under suitable laboratory conditions, bacteria can take up DNA from multicellular organisms – a result used to refute the idea that there were natural barriers between species.[4] They argued before political leaders that since the enzymes used in recombinant DNA experiments are similar to those found in nature, recombination across taxa probably occurs but at a low frequency. Since species barriers do not exist, they said, scientists have not breached them. Other scientists argued that only a small fraction of all possible genetic recombinations in nature have actually occurred. By 1989 scientists spoke openly again about natural barriers that could be breached by the new methods: "molecular methods (either alone or in connection with classical approaches) may permit the formation of novel combinations from distantly related genomes."[5]



Much of this debate over species barriers was a reaction to the prospect of laws restricting scientific inquiry and therefore the discussion never reached a high scientific or philosophical plane. When the concerns about strict controls over recombinant DNA technology subsided, the political discourse changed from the morality of breaching species barriers to the risks of moving genes across taxa. Would human intervention into the genomes of plants and animals introduce novel and potentially catastrophic risks?

Are there unique risks of gene splicing?

A special committee of the U.S. National Academy of Sciences reviewed the possible hazards of introducing into the environment organisms that were genetically engineered using recombinant DNA techniques. The committee concluded there was sufficient knowledge to assert with confidence.[6]

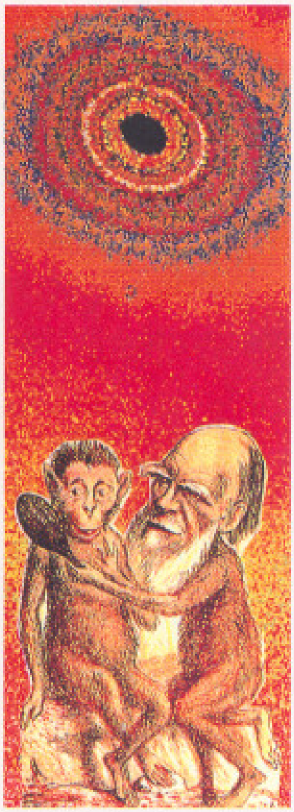
There was no evidence that unique hazards exist either in the use of rDNA techniques or in the transfer of genes between unrelated organisms.

The risks associated with the introduction of rDNA engineered organisms are the same in kind as those associated with the introduction into the environment of unmodified organisms and organisms modified by other genetic techniques.

No one doubts that, armed with a devilish scheme, hazards can be created with genetic engineering. How important is it that they are unique or not? In 1987 scientists at the National Institutes of Health raised litters of mice that had the genetic code of the AIDS virus incorporated into their genome. More than 100 mice were involved in the project presumably to develop an animal model to study the disease. Had a mouse escaped and mated with a wild relative, a new reservoir for the AIDS virus could have been established. Is this a unique hazard? It is theoretically possible that a mutated form of HIV could, purely through a natural process, deposit its genetic code into the germ cells of a mouse. Or, there might be other methods to create the same biohazard, some that do not involve gene splicing. Perhaps the issue is not the philosophical one of whether any process can yield unique risks, but whether some process can accelerate the chances of a risk event taking place. In sufficient time, nature can probably produce a PCB molecule; humans can do it more efficiently and in a much shorter span of time. Furthermore, had nature produced the molecule in abundance, humans most likely would have evolved with the appropriate enzymes to break it down.

Are natural transgenic foods an oxymoron?

The introduction of transgenic crops and animals into agriculture has brought into political debate the question: What is a natural food? Some companies have mar-



keted biotechnology as nature's own method of pest control, plant fertilization, or toxic waste degradation. While the public's reception to transgenic food, like the Flavr Savr tomato, has been mixed, multi-nation polls that show a significant majority of the public favoring labeling indicate that genetically modified food has not been accepted as a natural product.

Despite the public's perception, in guidelines issued by the US Food and Drug Administration, transgenic crops are considered no less natural than crops bred selectively. The agency decided not to regulate transgenic crops as it would food into which synthetic chemicals had been added. Critics argue that transgenic plants are not simple extensions of selective breeding emphasizing that certain gene exchanges (e.g., transferring a gene from a peanut to a tomato) would otherwise not be introduced by classical methods of hybridization. And what makes hybridization natural? Could the hybrid seed have arisen from the natural process of evolution?

The political struggle to control the symbol "natural" is best illustrated in the controversy over agricultural pesticides. In agriculture, natural is synonymous with organic which has been defined as a crop grown without synthetic chemicals (pesticides and fertilizers). Even though food produced without synthetic chemicals may contain fungi, insect viruses, and natural carcinogens, the term organic food is still viewed widely by the general public as natural and safe. Also worth noting, what could be the greatest food scare in the modern era - mad cow disease, is attributed to the transfer of natural proteins (prions) from one animal to another through the unnatural process involving the carnivorization of animal feeding.

The perception of biotechnology products as natural or unnatural will not be resolved by empirical study any more than our perception of hybrid corn or margarine. The classification of what is natural has more to do with the public's perception of risk and of its voice in technological choices than it does with some essential meeting of "naturalness."

Conclusion

Technology allows us to make mixtures of chemicals and now living things that nature, absent humans, finds useless. Some express doubt that our transgenic organisms, made in a petri dish within the blink of time can compete in the wild with highly evolved and diverse species that have, more or less, adapted to their environment. But even if human biotic creations are not made to repopulate wild habitats, they will bring human utility in artificially designed environments, such as farms and domestic gardens. But what happens if we take the next step either purposely or accidentally and begin to replace natural habitats with biogenetic constructions. Through the retrospective lens of evolution, time eventually tells us which characteristics of living things succeed, which fail, which habitats are in balance, which are vulnerable to rapid swings. In revolution, time is compressed, so that one cannot benefit from the steady pace of change.

The global ecological movement is premised on the idea that humans must live in harmony with the natural world. Now we are faced with the prospect that through respeciation we can make the biota adjust to human technology. Is this hubris or the next step in human evolution?

Before mankind emerged there were monkeys: Darwin was widely mocked for his concept of evolution, in which species appeared and vanished. With biotechnology species can be altered by incorporating genes in order to adapt these species better for life in a specified environment

---

[1] *Daniel C. Dennett, Darwin's Dangerous Idea, New York: Touchstone, 1991, p. 316*

[2] *Ernst Mayr, Population, Species and Evolution, Cambridge, MA: Harvard University Press, 1971, p. 13*

[3] *Cited in Sheldon Krimsky, Genetic Alchemy, Cambridge, MA, The MIT Press, p. 264*

[4] *Shing Chang and Stanley N. Cohen, "in vivo site-specific genetic recombination promoted by the Eco R1 restriction endonuclease," Proceeding of the National Academy of Science 74: 4811-4815 (November 1977)*

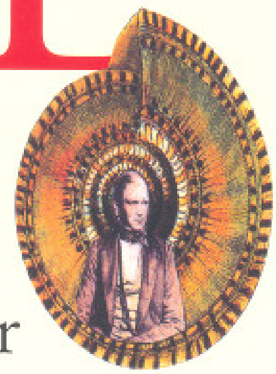
[5] *National Research Council, Committee of Scientific Evaluation of the Introduction of Genetically Modified Microorganisms and Plants into the Environment, Field Testing Genetically Modified Organisms: Framework for Decision, Washington, D.C.: National Academy Press, 1989, p. 83*

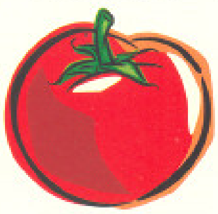
[6] *National Academy of Science, Committee on the Introduction of Genetically Engineered Organisms into the Environment, Introduction of Recombinant DNA-Engineered Organisms into Environment: Key issues, Washington, D.C.: National Academy Press, 1987, p.7*

Special Edition Biotechnology II/1997 Hoechst

FUTURE

Biotechnology: the wave of the future. It will change people's lives all over the world. Our planet has to feed an ever growing population. Medicine has entered a new era. Great challenges, great expectations. And a great demand for serious reflection and candid discussion





Human insulin: Genetic engineering makes it possible to produce large quantities and better quality. Insulin obtained from pigs can no longer meet the demand

Cambridge, Massachusetts and Martinsried near Munich: Hoechst is helping science form new bonds