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A Summary of: *Ecology and Genetics*

An Essay on the Nature of Life and the Problem of Genetic Engineering

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This monograph addresses three fundamental questions:

1. Is there a systemic relationship between genetic structure of species and the ecosystems they need for survival?
2. What are the implications of that relationship for the ecological damage that may be caused by inter-species genetic engineering?
3. Is it possible to predict ecological damage that may arise from inter-species genetic engineering with reasonable confidence?

The central thesis of this book is that the genetic structures of living beings are internal biological expressions of the external ecosystems they need to survive. The hemoglobin protein, for instance, is precisely structured so that oxygen can literally fit into it. It is also structured so as to absorb carbon dioxide and help transport it out of the body. Essentially identical hemoglobin-supported oxygen-carbon dioxide transport systems exist in a wide variety of living beings. One way to view the internal genetic structure that produces hemoglobin is that it has evolved as an internal expression of the external oxygen-carbon dioxide system that sustains life on earth, and has become, in the process, an important part of it.

The systematic correspondence between genetic structure of species and the ecosystems they need explains why living beings contribute to the reproduction of ecosystems in the everyday process of living. Living beings not only incorporate the external, for instance, by eating or converting carbon dioxide and water into carbohydrates, but also give back to the ecosystem in various ways, such as emitting oxygen, exhaling, creating aerated soil, and giving birth. The reproduction of the immense and complex relationships in nature could not occur if these acts were merely incidental to ecosystems. A global-scale symbiosis is needed to maintain the global ecosystem. Competition should be seen within that symbiotic context.

Take for instance, the oxygen-carbon dioxide cycles, essential to almost all life forms. These cycles are maintained by energy production, processing, and consumption, that is by the every day acts of plants and animals. The internal genetic structures that exist in all multi-cellular species (and many others) to maintain those cycles are also similar - they are the circular-shaped DNA of chloroplasts and mitochondria that characterize the energy production and processing systems in plants and animals. These circle-shaped DNA structures are not part of the famed nuclear double-helix DNA. They are not even located in the nucleus, but without them nuclear DNA could not replicate itself and death would be a certain and rapid result. In other words, the ability of nuclear genes to produce proteins depends centrally on the close relationship that the energy processing structure that mitochondria have to chloroplasts in plants, which create the energy supply from sunshine, carbon dioxide, and water.

Yet, the genetic structures of living beings do not contain complete internal information about their specific ecosystems, let alone the whole global ecosystem. The relationships of a living being to its ecosystem, including its relationships with other living beings, are mediated by environmental signals - sights, smells, and sounds - whose number and duration are necessarily limited. This means that uncertainties are inherent in ecosystem relationships, creating dangers, but also opportunities for evolution and symbiosis. Certain parasites flourish, for instance, because herons cannot detect them well enough in the fish they prey upon. But new symbiotic relationships can also arise from this tension. Mitochondria and chloroplasts in cells probably resulted from bacteria that infected eukaryotic cells and later evolved into the energy production and utilization system in plants and animals.

The competitive tensions and symbioses that result in evolution by adaptation over the ages have created a complex set of interconnected genetic structures. The near-total focus on the dissection of genes has resulted in important new understanding of life at the molecular level, but it also means that our understanding is fundamentally incomplete. We are faced with a serious deficit in the understanding of how the entire genetic structure of a living being functions, of the relationships between the genetic structures of living beings, and of the relationships of genomic structures to ecosystems.

Creating new genomic structures by inter-species genetic engineering would be a very risky proposition under any circumstances, but it is particularly rash in the face of the fundamental gaps in knowledge of how genomic structures express themselves in ecosystems. The toxicity of Bt corn pollen to monarch butterflies, for instance, is one example of how a new genetic structure is externalizing itself to create a new effect. Whether this particular case will have severe ecosystems impacts is beside the point. The fact of the creation of a new external ecological reality by a new, engineered genetic structure, corn containing a bacterial gene for pesticide production, is far more important. It is a huge warning signal.

An entirely new type of uncertainty is being created in ecosystems. The new genetic structures are not the product of co-evolution or even of the screening of genetic compatibility that is characteristic of traditional plant breeding. If Bt corn pollen looks and tastes like corn pollen but is laced with poison, does the monarch butterfly caterpillar have the genetic structure to enable it to tell? How widespread is the new biological ignorance of danger? How many different types of living beings may be affected and how? We simply do not know because the questions have only begun to be posed - after the fact of a massive introduction of genetically engineered Bt species. The normal uncertainties of existence, of life, death, competition, symbiosis, and evolution, have been turned into something much more risky. One researcher, Diethard Tautz, has suggested that if the modifications to the genetic structures do not threaten the immediate survival of the species being engineered then the long-term impacts may be impossible to discern unless the entire species is involved in experiment - an obviously self-defeating proposition.

Engineered species create two other dangers that we are only now beginning to glimpse. The first is the threat to food supply. The 430 million bushels of StarLink Bt corn that were recalled (StarLink was not approved for human consumption but wound up in food supply anyway), was enough to feed many millions of people. What if the recall had been a few times larger? Could we be faced with the choice of contaminated food or unaffordable food, if some future, even more difficult problem with greater immediate risks is discovered? The predicted persistence of StarLink corn in small amounts in the food supply for years to come has dramatically demonstrated the truth of biologist Erwin Chargaff's warning: "you cannot recall a new form of life."

An Australian genetic engineering experiment with mousepox virus (which does not affect humans, but is closely related to the smallpox virus) shows that genetic engineering may result in the creation by accident or design new creatures that are deadly and that can defeat vaccinations. The results of the experiment were a nasty surprise - the contrary of what was expected. The genetic modification was supposed to strengthen the immune system of the mouse. It weakened the mice to the point that most of them died and the rest were permanently disabled. The engineered virus even overcame mice that had been vaccinated.

The implications of the experiment for the creation of new agents of biological warfare are so serious that the results were kept under wraps for two years. But the technology of genetic engineering is now so commonplace and its raw materials as common as life itself, that the scientists decided that publication of the results to encourage public discussion and prevention strategies was a wiser course.

The spread of nuclear weapons has been limited by the great difficulty of obtaining plutonium or highly enriched uranium, neither of which is available in nature. So far, the industrial infrastructure needed make these materials is huge, costly, and easily detectable. None of these internal technological restraints apply to genetic engineering. Yet, society is proceeding apace with the widespread use of the technology without even a modest awareness of the dangers.

We have not even understood the ecosystem and social implications of genetic engineering well enough to have an informed debate on the subject. It is urgent that the recommendation of biologist Richard Strohman be adopted. He has suggested that "biogenetic engineering of humans and of plant where unanticipated results could cause damage to individuals or to millions of acres of cropland will have to cease except possibly under tightly controlled laboratory conditions." And the mousepox experiment shows that even laboratory manipulation carries serious dangers that need far more democratic debate than they have had.