The Uses of Evolutionary Biology

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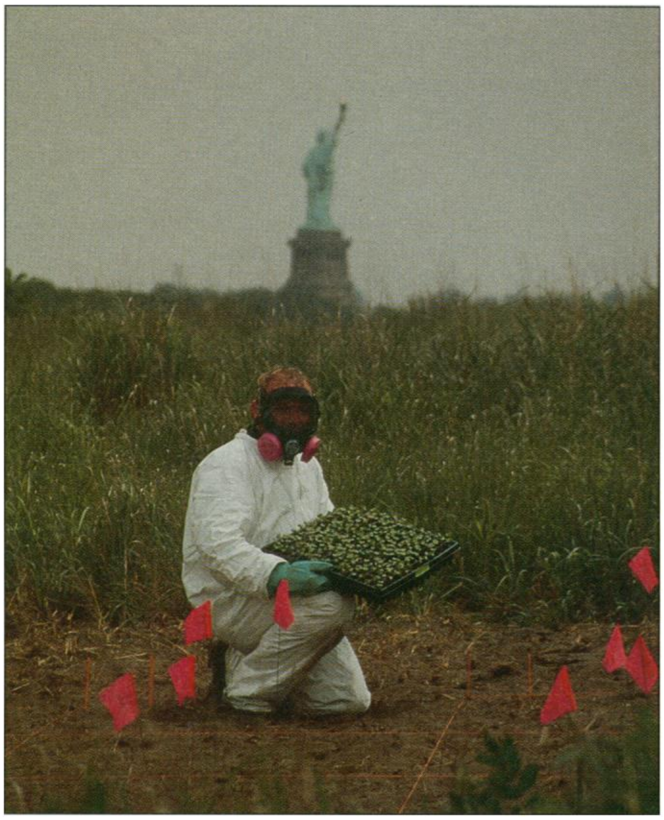
Evolutionary studies, unlike, say, molecular biology, are not generally thought to be very useful. To the extent that the general public is aware of evolutionary biology at all, it probably thinks of new dinosaurs or human fossils, or at best of new evidence on human evolutionary relationships. Politicians do not want to hear the word evolution. University administrators are likely to think that evolutionary science is nice to have around, like a Monet or a philosopher, but not really all that necessary (or lucrative) compared to physics or biotechnology. And most evolutionary biologists themselves, intrigued with the relationships of echinoderms or the adaptive significance of sex, are happily disengaged from the practical applications of their field to human affairs.

So it has seemed. But in reality, there have long been intricate relationships between applied sciences and evolutionary biology—taken to include not only paleobiology and phylogenetic studies but also genetic and ecological inquiries into evolutionary mechanisms, analyses of molecular evolution, and documentation of the diversity of life. Darwin (*1*) initiated a relationship between evolutionary science and plant and animal breeding that has grown ever more intimate (*2*); no entomology department, however much devoted to pest management, can pursue its mission without systematists and population biologists (*3, 4*); and conservation biology cannot exist without the population genetics, biogeography, and understanding of biodiversity that flow from evolutionary science and ecology (*5*).

These are among the traditional points of contact with the world of practical applications, but evolutionary biologists are awakening to the many other roles they can play—as are some representatives from the worlds of industry, medicine, and environmental management. Some of the potential for mutualism was explored at a workshop on *The Emerging Relevance of Evolutionary Biology to Applied Problems and Opportunities* held in Lawrenceville, New Jersey, on 13 to 15 May 1994 and organized by Laura Meagher (Associate Dean of Research, Cook College, Rutgers University) and Thomas Meagher (Director of the Graduate Program in Ecology and Evolution at Rutgers). About 45 representatives from academia (in evolutionary science, ecology, natural products chemistry, and other fields), industry, regulatory and funding agencies, and conservation organizations met to identify applications of and opportunities for evolutionary science and to recommend mechanisms for future interchange and technology transfer.



Researchers at Rutgers University, sponsored by Phytotech, Inc., conduct field trials of soil decontamination in eastern New Jersey, using plants that have evolved the capacity to accumulate heavy metals [photo by Ilya Raskin, Rutgers University].

Some of the applications of evolutionary science were obvious from the outset: In "Biodiversity and conservation," for example, evolutionary studies of factors that place populations and communities at risk of extinction [for example, inbreeding, reduced gene flow, specialization, and constraints on genetic and ecological responses to global change (*6*)] are clearly relevant, although much remains to be done. On the subject of "Phenotypic expression in novel environments," the points of relevance proved more numerous than some participants had earlier realized. For introduced species, and particularly for transgenic microorganisms and crops, how will the genome be expressed in new or human-altered environments? Can we predict gene expression, fitness, the likelihood of genetic exchange with indigenous organisms, and the probability of engendering new pests? The general predictive power of evolutionary theory may be limited in any one instance, but the tools evolutionary biologists use to study analogous problems in natural systems—molecular markers of gene flow, gene genealogies as evidence of gene exchange, analyses of phenotypic plasticity, and the "costs" of adaptation—are ready-made for transfer.

In the two other topics of the workshop, the relevance of evolutionary biology was undoubtedly surprising to both academic biologists and industry representatives. "Novel products and processes" include antibiotics (85 percent of which come from ascomycete fungi) and other pharmaceuticals, flavors, food additives, pigments, biopolymers, and enzymes, such as the Taq polymerase (isolated from thermophilic bacteria) that is the sine qua non of the polymerase chain reaction (PCR) and some parts of the biotechnology industry. This is big, politically sensitive business, in which a systematic rather than random search for natural products may provide the competitive edge (as, we were told, many European and Japanese firms well understand). Jennie Hunter-Cevera, from the Biotic Network, Cenito, California, and others in industry emphasized that even a superficial knowledge of adaptation and biological diversity can aid immensely in screening for new natural products, such as the Taq enzyme or enzymes capable of producing desirable metabolites at very low pH (*7*). Deeper knowledge of biodiversity, ecology, the functions of natural products, and phylogenetic relationships—that is, the subject matter of evolutionary biology—can be exceedingly useful in these endeavors. The need for more and better systematics emerged as a major recommendation.

In a similar vein, a role for evolutionary

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studies in "Bioremediation" was emphasized. For instance, tolerance of lead and other heavy metals has evolved in several plant species in contaminated sites, and such plants are now being studied in industry-university collaborative efforts for their role in land reclamation and bioremediation (*8*). The microbial communities that treat sewage and wastewater, and the naturally occurring or artificially selected bacteria that can metabolize polychlorinated biphenyls, heavy metals, and other pollutants are "black boxes" crying out for evolutionary analysis. How do new enzymatic capacities evolve, and how can such evolution be hastened (*9*)? Are there alternatives to genetic engineering (and thereby to what industry considers excessive government regulation)? Does coevolution in microbial communities facilitate bioremediation? Again, the role of phylogenetic analysis in identifying potentially useful organisms, the role of population genetics in tracing gene exchange within and among species, and the need for more systematics were emphasized.

Discussions on each of these topics generated much the same recommendations: Educate the public and policy-makers about evolution and eliminate the taboo against discussing it. Educate industry and applied scientists about evolution, and evolutionary biologists about research and employment opportunities in applied areas. Provide internships for evolution students in industry, and invite industry representatives to lecture to biology students. Above all, establish two-way communication.

Diverse as the topics of the Rutgers workshop were, they did not begin to cover the field. (Indeed, in recognition of the diverse current and potential applications of evolutionary biology, the workshop deliberately focused on selected environmental issues.) The well-known applications of evolutionary genetics in stock identification and other aspects of the management of fisheries, wildlife, and forest products were not discussed. Nor were many of the applications of evolution to agriculture emphasized. Identifying useful genes in wild relatives of crop plants; analyzing the evolution and genetics of resistance to pesticides and other control measures in insects, fungi, and weeds; tracing the spread of resistance genes; managing the evolution of pests' adaptation to pesticides, pest-resistant cultivars, and transgenic crops; modeling the "escape" of herbicide tolerance from transgenic crops to wild plants—in these and other areas, evolutionary science has contributed importantly (*4, 10*).

Perhaps the most conspicuous, although deliberate, gap in the conference was the relationship of evolutionary biology to the health sciences, possibly the most dynamically developing field of application. "Darwinian medicine" (*11*) uses principles of evolutionary adaptation to challenge medical orthodoxy on issues such as the causes of senescence (*12*) and the reasons for and the desirability of treating fever. Molecular phylogeny can clarify the origin of human immunodeficiency virus (HIV), hantavirus, and other new or resurgent pathogens (*13, 14*). Genetic and phylogenetic studies trace the rates of dispersal, contact networks, recombination, and evolution of virulence in viruses and other pathogens (*15, 16*), genetic diversity in bacteria (and their hosts), and the evolution, spread, and mechanisms of drug resistance in pathogens (*16*). Relatively simple principles of evolutionary epidemiology suggest why HIV causes acquired immunodeficiency syndrome (AIDS) after a variable latent period, when microbial parasites will evolve to be virulent or avirulent, and how the sometimes very rapid evolution of virulence might be discouraged (*17*). (The old idea that parasites always evolve to be benign is simply wrong. Selectively favored genotypes of parasites are those with the greatest rate of increase, which depends on the rate of transmission to new hosts. This in turn depends on the mode of transmission, the activity and longevity of the host, and often on the density of the parasite population within the host. When the latter is correlated with both virulence and probability of transmission, as it may be in mosquito-borne or sexually transmitted diseases, a high or intermediate rather than low level of virulence may evolve. Additional principles may affect the time of onset of AIDS, namely that the immune system imposes frequency-dependent selection for high genetic variability in a host's population of the virus; the disease may be initiated when a critical level of virus variation exceeds the immune system's capacity for complementary variation.)

As in every science, most evolutionary biologists practice not applied, but "curiosity-driven," basic research. But out of this has grown not only specifically applicable knowledge (for example, on genetic exchange among bacterial species), but more importantly, the concepts and analytical tools that can be immediately applied to practical problems: genetic analyses, phylogenetic methods, statistical methods, and the like. Most important, perhaps, evolutionary biologists are trained in a world view that is by no means universal but may be indispensable: One that recognizes that species are genetically variable in almost every respect; that species and their environments are highly complex, sometimes unpredictable systems; that nothing is constant in the fullness of time; and that technological quick fixes will have manifold but often predictable side effects and will provide only temporary solutions. "Nothing in biology makes sense except in the light of evolution" (*18*), it is often said, and both biologists and those who use biology are coming to understand that this light can illumine almost every aspect of our lives.

References and Notes

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19. I thank T. Meagher, L. Meagher, B. R. Levin, F. Gould, and J. J. Bull for advice and comments.