Intervening in evolution: Ethics and actions

Paul R. Ehrlich*

Department of Biological Sciences, Stanford University, Stanford, CA 94305

Biologists should help to guide a process of cultural evolution in which society determines how much effort, if any, is ethically required to preserve options in biological evolution. Evolutionists, conservation biologists, and ecologists should be doing more research to determine actions that would best help to avoid foreclosing evolutionary options.

There is no question that *Homo sapiens,* in addition to causing the sixth major spasm of biotic extinction (1–4), is also altering the course of evolution for millions of years in the future. Many of the important issues raised by that alteration have been beautifully laid out by Norman Myers (5). Here I explore three overarching questions. The first is a fundamental background one: Where do ethics come from? This leads to the second. Considering that just two or three human generations are dramatically changing the biotas that will comprise a major portion of the environment of tens of thousands of future generations, what ethical obligations might this impose on scientists to respond in various ways? And the third is: If we are ethically obligated, what might scientists do to be more effective in informing society of its options in this area? These are complex issues; I deal only with the tip of the iceberg here.

The ethical questions about intervention in the evolutionary process are very similar to questions about the closely related issue of the preservation of biodiversity (2). Most of us believe that people in the future should be able to obtain from biodiversity a wide variety of esthetic pleasures, ecosystem goods, and, especially, ecosystem services (6). Humanity is now faced with the prospect of a continuing loss of the populations (7) and species (8) that supply those values. But, beyond this loss, society is taking actions that will modify both the rate of evolutionary regeneration of populations and species and the nature of the replacements produced. Our acceleration of the rate of extinctions and modification of the evolutionary process immediately raises an ethical issue long recognized by economists and others (9) as that of ''intergenerational equity.'' The basic question is: At what rate, if any, is it moral for the current generation to discount the future? This question, in turn, leads us to the much more general questions of the origins and nature of ethical systems.

Where Do Ethics Come From?

Many people, following (most famously) Plato (10) and Kant (11), believe that, in essence, there exists a universe of ethics quite independent of the universe in which we dwell (or, equivalently, there is a god with all of the answers). To those holding that belief, answers to questions about the ethics of redirecting evolution have always been ''out there''; our task is simply to discover them. Others believe that ethics can be derived directly from the evolutionary process itself—that, basically, whatever behavior has evolved is good because it evolved (for an overview, see ref. 12). They contend that one can determine what ought to be from what is (a contention that is often called by opponents of this view ''the naturalistic fallacy''). I, and many others, take a third view (13): there is no extrinsic source of ethics, but human beings have evolved the capacity to hold and share values. Natural selection has, however, not helped us much in deciding what values to hold. The content of ethical systems—the things that a human being believes are right or wrong, moral or immoral—is assumed in this view to be almost entirely a product of cultural evolution.

Our dilemma of whether or how to change ethical systems so they can deal with human alteration of evolutionary processes assumes that cultural evolution is the primary source of values. After all, if there were an independent ethical universe we could tap into, it seems unlikely that ethics would differ as much as they do from culture to culture and time to time. A couple of centuries ago, slavery was ethically acceptable, as it had been since the dawn of history. It still is in some subcultures. An example, closer to the topic of this symposium, of cultural evolution that has altered ethics over the last few centuries is the widening of the circle of caring: the attribution of rights first to all human beings (as opposed to only some group of kin or pseudokin), then to domestic animals, then to charismatic wild animals, and eventually to all organisms and ecosystems. Furthermore, one can observe ethics evolving all of the time at a rate that cannot be explained by genetic evolution. It's happening at this meeting. No one was expressing concern about changing evolutionary trajectories even two decades ago. One could, of course, argue that the external ethical universe exists, and it is our communication with that universe or a deity that is continually culturally evolving. But that does not seem to be a very informative approach if we wish to understand the evolution of ethical systems. On the other hand, I see no sign that the process of evolution itself has provided many, if any, standards to undergird a system of ethics, including ethics about the maintenance of that process.

The evolution of ethics appears to be a product of a complex brain that evolved for, among other things, dealing with other smart individuals living in the same social groups. The roots of ethics seem to trace to the evolution of empathy—the ability to imagine another's viewpoint. Being able to consider the mental processes of members of one's group and relate emotionally to their states doubtless had a reproductive payoff and probably was a predisposition created by natural selection. But much of the behavior that ''evolutionary psychologists'' (e.g., refs. 14 and 15) and others attribute to genetic predispositions clearly can't be the direct result of biological evolution—we haven't the genes to do the job. Genes cannot incorporate enough instructions into the brain's structure to program an appropriate reaction to every conceivable behavioral situation, or even very large numbers of them. Here is an instance where a little bit of reductionist analysis suggests the hopelessness of seeking a genetic reductionist explanation of most of human behavior, including our ethical behavior related to the course of evolution (13). There are something on the order of 30,000 loci in the genome, whereas there are roughly 100 to 1000 trillion connections (synapses) between over a trillion nerve cells in our brains. That's at least

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*E-mail: pre@leland.stanford.edu.

one *billion* synapses per locus, even if every locus in the genome contributed to creating a synapse. Clearly, those connections can be only partially specified by genetic information; the environment and cultural evolution *must* play a very large, often dominant role in establishing the complex neural networks that modulate human behavior. To put it in shorthand, we could be said to have a "gene shortage," a point lost on popular writers in their enthusiasm to find "a gene" for every human behavioral characteristic (e.g., refs. 16 and 17).

Scientific Response to Human Modification of Evolutionary Trajectories

In this symposium, we are starting a dialogue over the ethical issues of human alteration of the future course of evolution, which can be viewed as an extension of the dialogue that already includes decision makers and the general public in discussions over human responsibility for abating the extinction crisis (18). I believe we can't look either to a deity or to evolution itself for answers. It is up to the human community to decide what the ethical course is, and to take whatever steps are then deemed ethically appropriate. Thus the answer to my second broad question seems to be that it is up to us as scientists to determine what are our own ethical obligations, and to help society at large to make its decisions.

Achieving some level of consensus on those obligations will not be an easy task. At one extreme, some will advise restoring huge areas of wilderness to provide evolutionary opportunities for continuation of megavertebrate diversification. That, clearly, is the view of those involved in the Wildlands Project (e.g., ref. 19)—and it's where I would come down emotionally if I could ignore the practical and ethical complexities of its implementation in most parts of the world. At the other extreme are the technological optimists who assume that genetic engineers will soon be able to produce any needed biodiversity to order and so see no reason to preserve what is left or worry about future evolutionary trajectories. They have a very high rate of discounting the future, because they assume that coming generations will be sufficiently richer and more technologically adept to solve any problems that altered evolution can present. This latter view will, of course, appeal to many in our gadget-oriented society, especially those who believe their financial security will be best protected under a "business as usual" scenario. And between those at the extremes (who will at least have considered the issue) will be the vast majority of humanity, people who simply see little reason to value most of biodiversity.

In the coming ethical debate, we must be extremely careful to take a broad view of the "human community" and not subconsciously assume that everyone shares the views of the community of evolutionary biologists, ecologists, and conservationists from rich countries. There is, understandably, considerable resentment in developing countries over what they view as a preference among conservation biologists for locking away land to protect biodiversity (and presumably future evolutionary options) without considering the present, sometimes dire needs of local communities or indeed of regions or even entire poor nations (20, 21). Choices will often have to be made between protecting the health and welfare of human beings living today, and risking those of future generations; evaluating such trade-offs and deciding on courses of action is likely to be difficult. For instance, revenue from logging a tropical forest might be used to help poor people living near the forest today. Would it be worth forgoing that revenue to preserve the forest as a potential generator of diversity that might improve the lives of people 2000 or 200,000 generations in the future? How are values to be assigned, and who should make this sort of decision? Is there any ethical need to consider the effects of today's actions that far or farther in the future? Could or should we strive to create such an ethical imperative? Can we possibly know enough to sensibly fashion an evolutionary ethic? Is it reasonable to imply an evolutionary discount rate of zero? Those who, like me, personally believe attention should be paid to the consequences of our actions for the long-term future must develop our arguments very carefully and not assume that there is a self-evident ethical need to do so.

Evolutionists, ecologists, and systematists can begin addressing these complex issues in four ways: through public education, interacting with those in other disciplines and walks of life, changing our research agendas, and working to find practical ways of influencing the evolution of ethics. Considering the long debate over the preservation of biodiversity (e.g., in the United States, continuing battles over the Endangered Species Act), it is clear to me that scientists concerned with answering the sorts of questions posed above and developing an ethics of preserving evolutionary processes will be caught in one of many mismatches in rates of cultural evolution (13). The speed at which society is changing the evolutionary prospect seems fated to remain much more rapid than the rate at which society is developing ethics to deal with the challenges that change may present. In this situation, the first and most obvious thing that we should do is alert the public and decision makers to the possible problem. I hope the colloquium on *The Future of Evolution* will mark the beginning of an effort by the concerned scientific community to do just that. Ecologists have gradually begun to realize that their responsibilities to society extend far beyond simply doing first-rate science and reporting the results in the scientific literature (22, 23). Evolutionists and systematists have lagged behind ecologists in awareness and action, but now is the time to start closing the gap (24).

Despite the uncertainties that are inherent in science, on issues of great importance to humanity, scientists must keep the public apprised of the latest consensus view of the pertinent scientific community (including recommendations for possible policy changes). Uncertainties, of course, should be made explicit in such communications, and when a scientist expresses a personal opinion diverging from the consensus, it should be clearly labeled as such. The idea that science should (or can) be value-free, a view expressed by several researchers recently (e.g., 23) and widely held in society, simply reflects a failure in the education of both scientists and members of the general public. The same can be said for the opinion that scientists should not make predictions about such things as future evolutionary trajectories because they may not be accurate, or the idea that one should wait until "uncertainties are resolved." Scientists, of course, make value judgments all of the time in their choice of projects (what is "worthwhile" investigating), choice of methods (e.g., how much disturbance of an ecosystem or injury to organisms would be justified by the information gained), and interpretation of results ("the most important conclusion from this study is . . ."). We cannot avoid such judgments, because being steeped in values is an important part of being human. The relative objectivity of science comes primarily not from the efforts we all make to be objective, but from adherence to rules (honesty, full disclosure of procedures, attempts to falsify one's own hypotheses), the adversarial nature of the enterprise (peer review, replication by others, eventual rewards for showing the paradigm has no clothes), and the existence of nature (an assumption) to serve as a final arbiter.

Making predictions is an important part of science, and a major challenge in the area of evolution is to make the best possible predictions on what human intervention means to the evolutionary process. We must seek ways that some of those predictions can be tested in the relatively short term. When the predictions are not fulfilled (they frequently will not be), the reasons for the failure should provide an entrée into finding just what part of the system was inadequately understood. And, of course, one thing that separates science from other ways of knowing is that uncertainties are never fully resolved. At best, the

community agrees that the uncertainties are minimal (although many a paradigm has crashed after such agreement), and individual scientists will always differ on the degree of trust they put in a given conclusion. Our credibility should rest on the openness with which we explain the uncertainties, our readiness to change conclusions and recommendations as new data come in, being clear on how our own views relate to the scientific consensus, and persistence in telling politicians that neither they nor anyone else can supply absolute certainty on a scientific issue. Credibility cannot and should not rest on an implicit notion that "science" in the abstract can be trusted.

A second way that evolutionists, ecologists, and systematists can contribute fully to the cultural evolution of ethics relating to future biological evolution is to participate increasingly in interdisciplinary research and interaction with people with different backgrounds and attitudes. We will wish to outline for society the likely consequences of alternative courses of action (or inaction) and, at least by implication, advocate certain courses of action. But without input from economists, political scientists, legal scholars, the business community, and others, some of the alternatives presented may at best have little chance of acceptance by society as a whole, or at worst produce results counter to those intended. Remember, it is not for us to dictate what society wants, but rather to interact vigorously with the public in an attempt to achieve ends that both make sense scientifically and are socially and politically feasible. As I indicated, in virtually all cases, society will be faced with increasingly difficult choices among alternate courses of action. Many will involve trade-offs between desirable outcomes, and scientists must help to clarify them. As individuals, not as scientists, we also may advocate our own preferences. The latter is important; although we cannot dictate a course of action to the rest of society, neither should we be disenfranchised when it comes to social decision making.

Third, beyond improving scientific outreach, we should be reexamining our research agendas so that they yield as much information as possible pertinent to evaluating the scale of anthropogenic impacts on the future course of biotic evolution, and attempting to find ways to ameliorate those considered potentially the most serious—as Norman Myers has been urging for more than a decade. The papers presented in this colloquium indicate that this process is finally underway, and much recent work is, perhaps serendipitously, pertinent to major issues. For instance, the question of whether isolation is the key to geographic speciation (25–27) or whether differences in selection pressures are equally or more important (28) is now being reexamined in some detail (29). The answer to that question could be important if society decides that it wishes to encourage the continued generation of diversity. If different selection pressures are paramount, then the unplanned trend toward reducing once-continuous tracts of habitat into many isolated but similar fragments will not enhance speciation to the degree that some may hope. In any case, we don't know enough to establish with confidence conservation priorities aimed to influence future evolutionary effects.

One example of a potentially fruitful research agenda is that of the new discipline of countryside biogeography (30–32). Ecologists and conservation biologists have recently started to realize that there is no longer such a thing as an undisturbed habitat—no pristine systems to study. They have begun to focus more attention on the ecology of organisms in the vast areas that have already experienced substantial anthropogenic disturbance. The goals of countryside biogeography include determining what elements of biodiversity are best able to persist in altered habitats, establishing the relationship between degree of intensification of land use and an area's conservation value, evaluating the importance of remnant habitat to the delivery of ecosystem services, and finding ways to enhance the conservation/service-delivery value of human-dominated countrysides. This work could also provide a foundation for what we might call "countryside evolution," which could examine the possible impact of various patterns of habitat alteration on evolutionary trajectories and seek ways to enhance the evolutionary potential of communities persisting in areas heavily impacted by human activities.

It is clear that the activities of *Homo sapiens* are dramatically altering the future course of biological evolution, and, if current trends continue, the degree of alteration is likely to accelerate and lead to substantial discontinuities. But the possible consequences of this for humanity are much less obvious, so it is hard to present specific options except self-evident ones such as: "if society wishes to preserve opportunities for continued diversification of large animals in groups such as the big cats, horses, antelopes, and our closest primate relatives, more effort should be put into the conservation of large tracts of wilderness." More broadly—and more importantly—environmental scientists today can simply recommend that those whose values include a concern for the options of distant future generations take more care when meddling in a process billions of years old, which, when severely perturbed, could change the biosphere dramatically for millions of years in unpredictable ways. We can and should do better.

Fourth, in addition to adding to the knowledge base that society will need in its decision-making, scientists should participate in the hard work of outlining feasible ways of accomplishing changes they deem advisable. Although the mismatch—between the rate at which society is altering the evolutionary future and the rate at which it is recognizing, evaluating, and taking action on the issue—is severe, we should not despair. The rate at which our society evolves new ethics to deal with various aspects of the human predicament, including the evolutionary dilemma, can be accelerated. Cultural evolution clearly can be directed (13, 33), but a determined effort by a large and diverse sample of people is required. This symposium must be just a beginning.

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