NEW QUESTIONS FROM THE NEW BIOLOGY

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INTRODUCTION

We live in exciting and challenging times. Advances in basic biological research have led to new, life-preserving medical technologies, and promise eventually to free us even from the thrall of genetic disorders. It is not unreasonable to believe that we and our children will be able to lead longer, healthier, and more productive lives than might have been envisioned even ten years ago, thanks to a deeper and more unified understanding of fundamental processes in living things. Associated with every advance, however, whether it be philosophical, scientific, or technological, are questions that no one had thought to ask, and implications that no one had foreseen. In most cases, these questions and implications reduce to new versions of classical ethical-moral problems. It is the contention of this essay that certain potential advances in the biological sciences will lead to questions that have never had to be considered up to now, and for which we are therefore completely unprepared.

My purpose then is to acquaint the reader with new and pending developments in modern biology, and, in the process, to indicate some of the questions and dilemmas that arise in relation to these developments. I fear that even questioning the directions/ implications of certain areas of modern biomedical research makes me an alarmist, apostate, or neo-Luddite in some scientific circles, but I strongly believe that all of us must participate in decisions relating to the shaping - and possible alteration - of the human species, and we are talking about nothing less than that.

NEW MEDICAL TECHNOLOGIES:
Life, death, and somewhere in between

The biological sciences and their associated "technologies" (e.g., medicine) have always been a source of questions about the nature of life and death. Medical philosophers continually grapple with questions relating to the allocation of scarce medical resources, the definition of death, the problem of when a fertilized human ovum can be considered a human being, etc. Less emotionally charged, but equally important, issues arise in relation to the treatment of non-human research subjects, the disappearance of some species and the alteration of others through cross-breeding. While the essence of many of these questions has remained unchanged over the centuries, the advancing sophistication of modern technologies has increased their complexity.

Examples in each of these categories are easy to bring to mind, since so many of them impinge directly on our own lives or those of our friends. "Triage" - the classification of injured individuals into treatment categories dependent on the severity of their condition - is a well-known form of decision-making about allocation of medical resources. Where medical personnel, supplies, and/ or equipment are the limiting resource, individuals who are critically injured are set aside, along with those injured whose wounds are not life-threatening. The intermediate group is thus treated first, the underlying idea being that the greatest number can be saved with the most efficient allocation of resources; those critically injured people who have survived the delay in treatment can then be taken care of, as well as the comparatively superficially injured.

Advances in medicine in the 20th century have greatly enlarged the "scarce resources" category without really altering the fundamental ethical questions that must be answered. Less than fifty years ago, penicillin was a scarce medical resource, and many individuals whose lives could easily have been saved died because of the limited amount of this antibiotic available. More recently, this category has come to include certain diagnostic tools (e.g., CAT scanners, imaging **NMR** devices, etc.), treatment apparatus (e.g., kidney dialysis machines, intensive care life-support equipment), and organs for transplant. **In** some cases, geographical location alone (big city vs. rural community) militates against fair and equitable access, while in other cases, resource availability can depend on money, age, "worth to the community," or simply the immunological characteristics of the individual.

Modern medical technology has also changed the fundamental definition of death. Cessation of heartbeat used to be the criterion for death, since the circulatory system could not be restarted once it stopped. However, the increased understanding of cardiac function has enabled medical personnel to repair and even restart hearts irrespective of the condition of other bodily systems, which partially or completely invalidates this criterion of death. The only organ whose cessation of function is currently irreversible is the brain. It is known that certain brain waves (monitored using electroencephalography) are associated with consciousness, thought, perception, etc., and that the flattening of these waves is associated with permanent loss of the functions monitored by them. Death can thus be defined in many otherwise ambiguous situations by the nature of the electroencephalography trace. It should also be noted here that, for the first time in humankind's existence, a working definition of death has arisen which is not based solely on physiology; the correlation of brain function with consciousness and perception implicitly defines what "personhood" is and determines a medical stance on the mind/ body problem.

The definition of "brain death" as death has itself created serious ethical problems. The same advanced technology that can be used to determine whether an individual is alive or dead can also maintain the physical processes classically associated with life long after brain death. The question of whether to "pull the plug" is a direct outgrowth of the conflict between the old and new definitions of death and, at this time, there is no uniform code; living wills having no legal validity, the burden of decision is placed on lay individuals who frequently are guided by the "old" criteria.

Even if they agree to "pull the plug" - due to a persuasive doctor or counselor, or simply for financial reasons - they are oppressed by a sense of guilt that can pervade their lives.

It is precisely because "brain death" is not a universal criterion that "pulling the plug" is considered a form of euthanasia. It is probable that future legal decisions, increased medical sophistication on the part of the lay community, and the simple passage of time will serve to ease the transition to a new criterion of death. However, the new medical technologies can also extend an individual's life long past the point that he or she might wish to live. At this point in time, the old question of euthanasia is increasingly coupled with the rather fuzzy concept of "quality of life;" one can request that no heroic measures be taken to preserve life under certain conditions, but the person most concerned with whether or not such measures are taken is often the one least in control of events. Such "passive" euthanasia often leaves medical personnel open to malpractice suits by relatives unless the relatives also agree to this course of treatment (or non-treatment) and, in the case of Baby Doe, even this may not be sufficient. And "active" euthanasia - helping a person to terminate his or her life - is still legally considered murder in many parts of the United States and the world.

There is yet another issue to be kept in mind for the future, the possibility that medical technology will advance to the point where even the brain can be "restarted". At this point in time, degeneration of the nerve tissues of the brain or severe damage to critical portions of it cannot be reversed and, in fact, part of the aging process is due to natural degeneration. But intensive research in this area is in progress, and it is probable that methods of neural tissue regeneration will soon be developed. What, then, will be the definition of death? And, perhaps even more important, will the person with the new neurological tissue be the same individual as the one before brain damage? If (e.g.) motor function has been impaired by a stroke, then repair of this portion of the brain would not affect personality. But there are other portions of the brain which appear to be associated with memory, emotions, and different kinds of thought. If THESE regions are damaged and then repaired, who is the person that will emerge after these procedures? What is their legal (and philosophical) relationship with their own pre-damage selves? With their spouses and relatives? In essence, then, such a technology could raise new questions about the old mind body / problem, as well as necessitating a new definition of the personality and of death.

RECOMBINANT DNA TECHNOLOGY:
Promises, promises ... (and threats)

The questions raised by current medical technologies are thorny and complex, but most are essentially new versions of much older questions. The same can be said for the animal rights movement, an outgrowth of anti-vivisection groups, and for other special interest groups who take a moral stance on biological or medical issues. However, in addition to what could be termed "classical" ethical and moral questions concerned with aspects of the biological world, there will soon be a whole new class of ethical problems with which we will have to deal, outgrowths of the new subdiscipline of recombinant DNA research (also called molecular biology, molecular genetics, or simply gene splicing). In effect, the logical applications of this young field are the repair and/ or modification of genes of all species including human beings, the addition of genes from one species to the gene set of another, and the creation of entirely new genes. It will be both a philosophical and a biological problem to determine how much and what types of genetic change can be made without altering the fundamental nature of a given species.

Recombinant DNA techniques have emerged from intensive studies of the genetic and biochemical mechanisms by which genes and their products are expressed (made) and regulated. After the determination of the structure of DNA in 1953 and the subsequent decryption of the genetic code, progress in this area was extremely rapid. At this point in time, most biologists have a clear idea of the general mechanisms governing the relationship between the genome (the set of all genetic information) and the expression of the genome in the form of gene products (proteins of various sorts), although the particular aspects of a given part of the total picture are still unknown.

At the same time that these mechanisms were being elucidated, a number of new enzymes involved in the processes were found and characterized. One type of enzyme, called a gyrase, is concerned solely with unwinding the double helix of DNA so that copies of the code (messenger RNA) can be made. There are repair enzymes of various sorts, which mend breaks in the DNA and, where necessary, fill in missing bits of the helix. And there is a third class of enzymes, called the restriction enzymes, which recognizes certain base sequences on the DNA and cuts the helix at those points. Finally, there are reverse transcriptases, enzymes which read RNA messages and synthesize the DNA code from them. In essence, then, the tools necessary to make a copy of a particular DNA or RNA sequence and insert that sequence into an already existing genome can be found naturally. Combined with advances in understanding how viruses work, it is theoretically (and practically) possible to transport a gene into a given set of target cells using a virus packaging mechanism, and insert it into the cell's genome.

Thus, copies of genes can be switched around from one organism of a given species to another, or between species, or even between phyla. This is the kind of work being done in the new genetic engineering companies, where the human genetic sequence for (e.g.) insulin is inserted in multiple copies into the genome of a microorganism such as E. coli, turning the microorganism into an insulin-producing factory. It is also possible to "design" new genes or modify already existing genetic sequences (i.e., write one's own code) and get them inserted into an already existing genome. Many protein scientists are using this technique to study the process by which proteins fold up into their active structure, to test which amino acids in a given sequence are "essential" for activity or folding, and even to test predictions of which types of amino acids are involved in different types of internal protein substructure (e.g., alphahelices vs. beta-sheets). Finally, there are continuing attempts to "tailor" new organisms with unique metabolic activities. One example of this is the work on microorganisms that might use toxic waste or spilled oil as "food", breaking these materials down into forms that can be incorporated into the natural food chain.

These current research activities all have praiseworthy goals - production of scarce biomedical materials (enzymes, hormones, etc.), cleanup and preservation of the environment, and basic studies of intrinsic natural mechanisms. At the present time, some of this work has run into technical difficulties. In some cases, when the gene from a higher organism is transferred into a microorganism, it does not seem to be "read" properly, resulting in the production of proteins that do not work. In other cases, the transfer is successful, but the new strain created is either unstable or not particularly viable. Both of these difficulties have been used by recombinant DNA technologists as arguments for the easing of controls on such research, along with a third argument - that such recombinations occur in nature and have not yet destroyed the environment or a given specIes.

Currently, recombinant DNA research guidelines are formulated by the National Institutes of Health, which can enforce them ONLY for research supported financially by them. These guidelines are extremely anthropocentric, placing strict controls on manipulation of human genes, and relaxing the rules as the genes become phylogenetically more distant from the human. It should also be noted that the present NIH guidelines are much less strict, even for human genes, than they were only a few years ago. The techniques are so well documented and worked out that recombinant DNA manipulations have become "cookbook" procedures that are often performed by technicians, technical assistants, and even college undergraduates. Kits containing all the necessary enzymes and instructions for use can be purchased from a number of companies, and are being used in teaching laboratories at a relatively low undergraduate level as well as in research labs.

Like any other scientific advance, the development of recombinant DNA technology has its good and bad aspects. The production of needed biological products, such as human insulin and human growth hormone, is a tremendously important advance both for the increased availability of scarce medical resources and for the design of new strategies of treatment for infants and children with deficient endocrine systems. It also provides the hope of an answer to the ever more threatening problem of the poisoning of the environment, especially our water systems. On the other side of the coin is a Frankensteinian nightmare of microorganisms running amok and destroying the very things they were designed to preserve. E. coli, the microorganism generally chosen for genetic modification, lives in a human's large intestine and is involved in food metabolism. (The often-experienced diarrhea associated with a course of antibiotic treatment is due to the antibiotic killing off the E. coli and other needed intestinal flora.) If a modified variation of E. coli is also viable and escapes from a laboratory, it could wipe out a large segment, if not all, of humanity. Humanity could also be destroyed, along with the rest of the biosphere, by any other viable microorganism which, when released, interferes with one or another segment of the food chain; this threat is what makes the anthropocentrism of the NIH guidelines so potentially dangerous.

Because a disaster has not yet occurred does not mean that it could not happen sometime in the future. There have been at least two outbreaks of smallpox in England since it was officially eradicated there by the World Health Organization, due to poor laboratory technique and inadequate containment facilities. Stocks of this virus remain in several known locations around the world, including the Center for Disease Control in Atlanta, and it is probable that secret military stockpiles also exist, but for obvious reasons, there are few sources of vaccine remaining or of individuals who are immune. It is not beyond the realm of possibility that a similar situation could arise from genetic manipulations, but we are even less prepared for that eventuality than for the reintroduction of smallpox into the world.

In the mid-seventies, scientists involved in the development of genetic technology met in Asilomar, California. They were concerned about the implications of this kind of work, and the possible threat to humanity and to the environment it posed. They agreed to a moratorium on all such research until its full implications had been studied, but because this agreement was not unanimous, the moratorium lasted about as long as it took the scientists to get back to their laboratories. More recently, a group of scientists from Harvard and MIT attempted to get the Cambridge city council to pass a law preventing such research within the city limits. This, too, failed, but the animosities aroused between those in favor of this work and those opposed to it remain to poison the collegiality of a number of departments at both universities.

The risks and benefits posed by the current state of recombinant DNA technology do not, as such, constitute a philosophical problem so much as an environmental one. The potential problems discussed above are essentially of the same type as those created by any disease-related research or by the production of hazardous wastes (chemical or radioactive). Like these more familiar threats, the risks involved in recombinant DNA technology can be minimized or eliminated by the proper controls and facilities, as well as by strong and consistent enforcement of the rules. Contained within the current state of the art, however, are the seeds of what will someday soon be a more fundamental problem.

RECOMBINANT DNA TECHNOLOGY:
Better living through gene manipulation

Many "diseases" are actually not diseases at all, but genetic problems. Either a gene product is not made or the gene product is aberrant; in either case, this results in disorders which can be extremely severe. Phenylketonuria, for example, is a genetic disorder of the metabolism: phenylalanine, an amino acid, is not converted to tyrosine, another amino acid; because of the buildup of phenylalanine, alternative metabolic pathways are used, and other products are made in nonphysiological excess. If not identified at birth, this condition can cause extreme mental retardation (note the warnings to phenylketonurics on products containing Nutrasweet). Newborns are now routinely screened for this condition and, where found, the affected individual must maintain a restricted diet for life. Other genetic disorders include sickle cell anemia, hemophilia, many forms of muscular dystrophy, and vitamin B-12 deficiency. In addition, there is increasing evidence that predisposition to certain forms of cancer may also be genetic.

The advances made in the last 50 years in the understanding of the basis and expression of such disorders has led to the preservation of the lives of individuals who would otherwise have died. Of course these advances have also led to the possibility of these individuals having children and passing on lethal and semi-lethal genes that would otherwise have been eliminated from the gene pool, genetic counseling notwithstanding. However, within the next decade or two, it should be possible (in those cases where the aberrant gene product has been identified, and the gene located within the genome) to use recombinant DNA technology to replace the "bad" gene with a normal one by using an infectious virus as a carrier. Since a female's ova are generated prenatally, this will not prevent transmission of the bad gene into the genetic pool (and in fact will increase its relative amount in the pool), but it WILL allow affected individuals to lead normal lives of a normal length. Eventually, the technology will progress to the point where lethal and semi-lethal genes can be detected and replaced early enough so that they will not be passed on to future generations, possibly at the stage of the unicellular fertilized egg.

It is estimated that almost all living humans carry at least one recessive gene which, if not masked by a complementary "normal" one, would be lethal or semi-lethal. For every human born, there are several spontaneous abortions of non-viable genetic material, almost always too early for the female to know that fertilization has even occurred. So the elimination of these potential genetic disorders is an important and valuable goal. But why stop there? Presumably by the time that this technology has developed to the point where such permanent changes to the human genome are possible, many or most of the other genes will have been identified, located, and transcribed. So, at the same time that the albino recessive gene is being replaced, why not also specify sex, height, eye color, and body build? While getting rid of that set of genes that results in near-sightedness, how about arranging for gills and webbing so that our child can never drown? And if certain other skills - such as logical reasoning, visualization of spatial relationships, perfect pitch, and/ or artistic prowess - are even in part genetically determined, why not give our amphibious child a head start in the scholastic jungle? Finally, since there is some evidence that the aging process may be partially genetically determined, how about increasing his/ her lifespan? Or, if aging is instead due to the lifetime accumulation of certain toxic materials, why not tailor some E. coli or whatever to deal with these substances?

Using the recombinant DNA technology of the near future, we can fashion healthy, long-lived, amphibious, intellectually and artistically gifted individuals. With the possible exceptions of webbed feet and gills, each of these genetic alterations is within the range of human potential, although badly skewed toward one end of the scale. Other permanent alterations outside of this range are also possible; in addition to the gills, it might be important to thicken the skin and/ or change the distribution of the blood supply to reduce heat loss, or alter the nature of the skin texture and body shape to make the individual more hydrodynamically streamlined. In addition, since the amount of light underwater is much reduced from that in air, and the chromatic composition of it changed by solutes in the water, it might be important to change aspects of the visual system (e.g., extend the visual range into the infrared and/ or ultraviolet; increase the size of the pupil; alter the mechanism of focusing to compensate for the loss of the corneal contribution to light refraction by the eye, etc.), or even add the capacity for echolocation (sonar) like that of dolphins and whales.

Our amphibious individual has been endowed by its creators with sizeable portions of the human genome, the "best" qualities in the range of each trait or talent selected for. In addition, certain physical capabilities have been added which are outside of the human range of natural genetic possibility. Is this entity human? Amputees, paraplegics, and morons are all considered human, as are Olympic champions (though their gender may be in doubt), idiot savants, and geniuses; i.e., a human being is not defined by IQ or a physical description. So in the sense that "brain death" is death and mentally and physically handicapped individuals are nevertheless unquestionably human, so is our water-breathing friend a human being. But how much of the human genome can be replaced or augmented with genes outside the current population norms before we become uncertain in our identification of what is human and what is not? This is a crucial consideration in itself, but also leads to the question of the effect of human genetic changes on the nature of humanity as a whole.

In this larger sense, any permanent alteration of the human genome, whether within the human range or augmented outside of it, alters the nature of humanity by altering the distribution of potential traits within the population. Such genetic changes could also alter the nature of human interactions in ways that we cannot currently imagine. E.g., the increase in longevity we can expect right now on the basis of medical progress has already altered our society in significant ways: attitudes toward work, the role of government, social values (including increased separation between the generations), marriage and divorce, medical practice, the self-image of older individuals, and innumerable other aspects of our culture. What changes might be expected if the life-span were doubled or tripled? How would this affect the decision of when and whether to have children, for example, and/ or how they are raised?

Extending this example of an increase in life-span to include other changes in human characteristics (both physical and intellectual), the social and biological implications are enormous. It might well be valuable to extend our life-spans, eliminate near-sightedness, and replace all the "bad" genes, but is it equally valuable to select specifically for certain types of mental skills that we currently class as intelligence? What will we gain from that and, even more important, what might we lose? What is our ideal of a human being? And how much of that ideal, if any, transcends evanescent cultural values? What does being human mean? In summary, any significant genetic change in sizeable numbers of humans will be inextricably linked to changes in the nature of humanity itself: physically, mentally, emotionally, and culturally. Before we begin to significantly alter the human potential, serious thought MUST be given questions relating to what a human being is and what humanity is (and might become).

GENE SPLICING AND SOCIOBIOLOGY: A dynamite combination

It is the contention of the relatively new field of sociobiology that much more than physical characteristics and mental abilities are genetically determined, at least in part, in humans. In contrast to the completely plastic personality visualized by Skinner and the behaviorists, many sociobiologists believe that such philosophical abstracts as altruism, aggression, and affection may be governed by one's genetic makeup. Sociobiology as a discipline is thus the study of the genetic basis of social behavior.

At this point in time, sociobiology has been very successful in increasing the understanding of the behavior of social insects and, to a lesser extent, social behavior in higher organisms. Its applicability to human behavior, however, is still open to question. There is the understandable tendency to justify the importance of an infant discipline by making sweeping claims for its special insights, as has been done in several books by E.O. Wilson generalizing from the insect to the human. This is countered by others, such as Richard Lewontin and associates, who take particular pleasure in pointing out the often serious flaws in studies used by Wilson in making his generalizations. The Lewontin et al critique is written from a Marxist point of view, which has seriously weakened the effectiveness of their effort to oppose a sociobiological view of humanity, but does not affect their devastating analyses of key studies.

At this point in time, there is little or no hard evidence justifying the generalization of sociobiological concepts to humanity, so any conclusions about the genetic basis of human behavior would be very premature. Unfortunately, the concepts underlying sociobiology have been misinterpreted and misused by a few scientists and a number of lay people outside the field to justify their personal prejudices. These individuals, the intellectual and political descendents of the social darwinists, extreme eugenecists, and Burt-Shockley racists, believe that sociobiology provides a (pseudo)scientific foundation for making (unwarranted) distinctions between racial groups and even social strata within a particular society. Like these previous "sciences", sociobiology (which in its implications is deterministic and reductionist) is used to rationalize the status quo. You do not have to be a Marxist to recognize the political and social implications of the misuse and/ or premature application of sociobiological ideas to humanity, nor to be concerned by the increasing popularity of this point of view.

For the sake of argument, however, let us assume that the sociobiologists are absolutely right in their idea that all aspects of human nature (as it were) are at least partially genetically determined. Let us assume, furthermore, that the genes governing these aspects are identified and located in the human genome. Then, just like physical characteristics and mental abilities, they can eventually be selected for (or against) on a permanent basis. What would a society with an excess of altruists (or no altruists at all) be like? If there are no longer any threats from lethal or semi-lethal genes, would there be any need for an incest taboo (either societally or genetically determined)?

To take a less obvious example, what would the world be like if everyone were non-aggressive? How would this affect the nature of our society or, equally important, the ways in which other aspects of our humanness are expressed? What relationship might there be between aggression and ambition? Between aggression and creativity? Between aggression and sexual response? What would happen if, instead of 100% non-aggressive individuals, there were 99.9% non-aggressives and 0.1% aggressives?

The nature/ nurture controversy has been with us for many years, with different schools of behavior assigning different weighting factors to the two halves. Lewontin and coworkers have suggested that, whatever view one takes on this issue, it becomes a fundamentally reductionist and deterministic description of human potential. Their own view is that the development process is a dynamic and synergistic relationship where, in effect, the whole is greater than the sum of its parts. However, whether one agrees with Lewontin or takes a more usual stance, there is no question but that changes in the distribution of even simple physical traits can change society and individuals growing up in that society in ways that we have not really thought about, as shown in the previous discussion of increased longevity.

If we extend the discussion of the nature of humanness to include, not only physical traits but also manual skills and intellectual gifts, it is clear that skewing the human range of potential through genetic manipulation will have unforeseen and perhaps unimaginable effects. And by adding into consideration the possibility that, as the sociobiologists contend, ALL aspects of "human nature" are genetically determined (at least in part), we are faced with a situation where we are capable of altering ourselves completely as a species. The augmentation of human capabilities, either physical, mental, or emotional, outside the current human range is equally possible, but does not even have to be considered seriously at this point, since the promise and threat to ourselves within the human range of possibility is itself awesome.

WHERE DO WE GO FROM HERE?

It is likely that the reader is, by this point, ready to dismiss all of what has gone before as science fiction. (In fact, many science fiction writers have been deeply concerned with the issues raised here, and have explored their implications in a number of short stories and novels.) However, it is precisely because we are rapidly approaching a time when renewal of neurological tissue, replacement of defective genes, etc., will be within the realm of possibility that asking what humanness is and what we want ourselves to become is so important. It is possible that we will lose, not only our variety as unique individuals, but also the potential for development in currently unknown directions by altering the nature of the human gene pool. We will certainly be altering our human societies in fundamental fashion. The problem that faces us now, and that will become more acute in the near future, is not whether such technologies will be used, but rather how we use these technologies to their best effect. In order to cope with these dilemmas of the future, we have to obtain a clearer understanding now of what makes us uniquely human.

REFERENCES

Because modern biology is such an enormous area, it is difficult to suggest references which can provide a relatively non-technical, but accurate and objective, introduction to the area. Most introductory college-level biology textbooks provide a general introduction to recombinant DNA techniques, however, and the most generally used college textbook for an introductory course in molecular biology is James Watson's *Molecular Biology of the Gene* (WA. Benjamin, Inc.)

E.O. Wilson has written a number of technical and non-technical books about sociobiology, including:
Sociobiology: The New Synthesis (1975) and
On Human Nature (1978).

Both are published by the Harvard University Press. A less arduous book is *The Promethean Fire,* co-authored by him. The major response to the sociobiological thesis is:

R. C. Lewontin, Steven Rose, and Leon Kamin. *Not in Our Genes: Biology, Ideology, and Human Nature.* Pantheon, 1984. It is unabashedly Marxist in stance, but the authors' contention is that sociobiology is itself political (and not objective science). Reading any of the Wilson books, followed by the Lewontin et al. book, is an excellent way of becoming thoroughly familiar with the geography of this battlefield.

For the description and discussion of recent advances in biology and medicine, read your local newspaper. *The Science Times,* published every Tuesday in the *New York Times,* often has articles that are relevant to the subjects discussed in this essay (e.g., on6/9/87, there was a long article on the economic, ecological, and ethical implications of "gene-engineering" animals.) Some of the ethical implications of these, and more standard biomedical issues, are discussed in journals like *"Issues in Science and Technology"* or in the news sections of professional scientific journals like *"Science"* and *"Nature".* In my personal opinion, however, the very best exploration of the implications of some of the current and potential advances in biotechnology can be found in science fiction magazines, short story collections, and novels.