REFLECTIONS ON SOME SOCIAL IMPLICATIONS OF MODERN BIOLOGY

by Robert S. Morison

I would like to begin with a brief, overall look at the relation between science, especially biological science, and ethical decision making. By what sort of right or with what qualification may a scientist talk about things which scientists previously were supposed to know nothing about and probably still actually know nothing about?

Let us begin by asking why scientists worry about questions of ethics at all and then proceed to what science may have to offer. There are various levels, of which some are pretty obvious and some a little bit esoteric and controversial. After this introduction I shall propose three general statements that I think science can make about man and that seem to be significantly related to questions of value. I will explore the last of those statements in some detail since it underlies and conditions the theme of this conference. Specifically, I will discuss the biological advantages and disadvantages of human variation and how these bear in turn on some questions of social importance. I will close with a few remarks on the technical possibilities for correcting or preventing the appearance of some of the more extreme variations from which human beings now suffer.

Scientific Contribution to Ethical Discussion

Let us turn back, then, to our first question, What has science got to do with the problem of value? The conventional answer until shortly after World War II was, Nothing at all. Those who were sophisticated in the philosophical background of science were accustomed to quote Hume's *Treatise of Human Nature:*

> In every system of morality which I have hitherto met with, I have always remarked that the author proceeds for some time in the ordinary way of

Robert S. Morison, Class of 1949 Visiting Professor, Massachusetts Institute of Technology, presented this paper at the Twenty-second Summer Conference ("Genetics, Biological Evolution, Ethics") of the Institute on Religion in an Age of Science, Star Island, New Hampshire, July 26–August 2, 1975.

[*Zygon,* vol. 11, no. 2 (June 1976).]

reasoning and establishes the being of God or makes observations concerning human affairs, when of a sudden I am surprised to find that instead of the usual compilation of propositions, *is* or *is not,* I meet with no proposition that is not connected with an *ought* or *ought not.* This change is imperceptible, but is, however, of the last consequence, for as this *ought* or *ought not* expresses some new relation or affirmation, it is necessary that it should be observed and explained, and at the same time a reason should be given for what seems altogether inconceivable, that this new relation can be a deduction from others which are entirely different from it.[1]

The tendency to mix up *is* and *ought* is called, in other contexts, the naturalistic fallacy. Its dangers have been lucidly and briefly explained by Antony Flew in his *Evolutionary Ethics.*[2]

In the late nineteenth and early twentieth centuries this ancient problem of is/ought was put into modern clothing by Max Weber in an essay on fact and value and the importance of keeping them apart.[3] In order to avoid confusing the two, most social scientists steer clear of value questions as much as possible. Incidentally, many of us natural scientists, not fully informed of this history, had rather assumed that it was part of the business of social scientists to look after the value problems in social behavior. It seemed natural enough to invite them to help in solving some of the practical ethical problems surrounding such matters as organ transplantation or human experimentation. It soon developed, however, that only a few, rather maverick social scientists were very helpful or even interested.

In summary, then, there has been a long tradition of self-abnegation on the part of both natural and social scientists in the treatment of values. Scientists were not only restrained by this imperative but also excused. The attitude was, "We find out what is, and you people out there in society decide what ought to be done with the knowledge." This attitude provided, among other things, a convenient end to the long-standing war between theology and religion.[4] Once a sharp line was drawn between fact and value, philosophers and theologians felt a bit better because they could say what they pleased about value without interruption; and the scientists on their side felt better because they could work in their laboratories without being held responsible for anything that happened as a result. This comfortable truce changed very sharply with the advent of the atomic bomb. The bomb was built in the first place because two scientists, Leo Szilard and Albert Einstein, wrote a letter to President Roosevelt saying, in effect, that such a bomb could be built and that it ought to be built because there were socially desirable reasons for using it. They thought of themselves as acting as responsible people since their value system required that they do everything they could against the Nazis.

In a surprisingly short time after this original letter, the bomb was indeed dropped; and, shortly after that, the scientific community began to encounter feelings of guilt. Robert Oppenheimer put these feelings on record in his famous statement that, in some sense, physicists had now known sin. From then on science was in the value business. Concrete evidence of the change is found, for example, in the founding of the *Bulletin of Atomic Scientists* to explore the proper use and control of atomic energy and later to deal with the social impact of other scientific advances. Jumping rapidly over a decade or so, we find another landmark in Harry Beecher's article in the *New England Journal of Medicine,* calling attention to several experiments on human beings which he regarded as unethical.[5] Another, more recent landmark is the Asilomar Conference, at which a group of geneticists agreed to a set of rules for keeping certain types of genetic experiments from doing harm to people. There is still much to be done in developing a sense of ethical responsibility for the development and use of scientific knowledge, but at least we now recognize and accept the problem. Indeed, in view of the earlier history, rather surprising progress has been made in the relatively short time since World War II.

We turn now to a more challenging and still very uncertain question, Does the scientific way of looking at things have something to offer to the solution of value problems? Can there, after all, be something normative about science? To somebody of my background and training there is something embarrassing about even asking such a question. Perhaps it is only because I have become too old to care that I dare to do so. The first sort of approach may be quite obvious and not really very frightening, but we ought at least to mention it here for completeness. Science is able to define certain sorts of problems, to outline their consequences, and to give probability statements in relation to the risks of certain courses of action. In developing this role, it has come increasingly to a sense of responsibility for helping the public to understand what is likely to result from the use of new technologies. The obvious case of the atomic bomb is illustrative. Scientists have continued to remind everyone that we now have numbers of bombs which make it possible to kill probably ten times the present population of the world and very likely make the northern hemisphere uninhabitable. It is important for scientists to point this out and to keep saying it because it is hard for people to imagine by themselves. The general public has no experience with power of such dimensions; and it took a long time for the concept to filter into the minds even of the people in the Kremlin and our own people in the White House. I am not sure that some of them fully understand it yet.

In the same vein, scientists have pointed out that it is possible to poison the ocean. We used to think of the ocean as an infinite sink, but we find now that we have already put things into the ocean that do not disappear very rapidly. The same may be true of the air. Scientists clearly have an obligation to point out such things simply because they are the people who know most about them. Furthermore, most scientists owe what knowledge they have to the support they have received for their education and their research from public funds.

In their role as discoverers and definers, scientists in a sense may create value problems where none grew before. In some cases, the very precision of definition and of the prediction of things to come helps in suggesting answers to the questions involved. Indeed, scientists frequently may use their knowledge to develop useful new procedures which can cure long-standing ills or in other ways promote human welfare. The existence of such procedures in turn puts pressure on society to do something good and useful with them. When the nutrition people showed, for example, that a certain form of insanity associated with pellagra could be cured by taking one of the B vitamins, or, somewhat earlier, when quasi scientists showed that scurvy could be prevented by drinking lemon juice, these discoveries implied an obligation and responsibility to make these things generally available. Thus one of the important ethical roles of science is to point out what is possible so as to stimulate other people to take the measures necessary to improve human welfare.

Another kind of scientific contribution to ethical discussion is illustrated by the following example. Not long ago science was able to point out that abortions early in pregnancy are safer than normal births. This information took away one of the strongest arguments —indeed the primary argument cited in the early legislation in this country—against abortion. Making abortion safe for the mother changed the nature of the ethical argument. No longer could one avoid the philosophical issues by taking refuge in pragmatic arguments about preserving the mother's health by making abortion illegal. For many people, the pragmatic argument reversed its field completely. Preserving the mother's health by making abortion both safe and legal took precedence over more metaphysical arguments about the sanctity of the fetus. However one may feel about the rightness of the outcome, there is no doubt that the progress of medical technology and scientific analysis of results greatly influenced the ethical argument.

Finally, I shall just note in passing one other, rather different, perhaps somewhat ironic result of the ability of science to put tools in the hands of people for doing good. Consciousness of the implied responsibility may actually turn some people against science since, for example, they can no longer unload responsibility for high infant mortality rate by pleading that God willed it that way or that it was simply in the nature of things for many young children to die.

Another kind of contribution is controversial since it bears the most closely on the Humean command not to mix up is and ought. That is the question of whether science, by describing man's nature and his place in nature, can suggest anything in the way of how he ought to behave. To give a quick and tentative answer, I will say that it cannot give simple directions of a specific sort, but it may be able to suggest general guidelines or constraints or limits on what is possible in the human condition and thereby in a very general but still important way contribute to the solution of value problems. This is as far as I dare to go, and there are many scientists and philosophers who would feel that I have gone too far already.

Prescientific World View

It may make what we are trying to find a little clearer if we go back and remind ourselves how people looked at the world before the scientific era, before, in other words, the split between the humanities and the sciences which C. P. Snow described in terms of two cultures.[6] Until the Renaissance, men liked to think of the world as a unity. Living things and dead things were not so different from one another as they later became; the physical world, the biological world, and the spiritual world were all part of one great design, presumably produced by a great designer. Inanimate things behaved according to this great plan. Men also were part of the great design which in turn determined the way they ought to behave. Thus there was very much less distinction between is and ought than was made in the Enlightenment by Hume. Indeed, most of the Greeks felt that the way to find out how to behave was to find out what was in God's mind when he designed the world. The way to discover that, the Greeks recommended, was through the use of what later became known as right reason. About the same time the Jews developed somewhat the same notion but with a different twist. They said that man should behave in relation to God's commands—not so much his designs as his commands—and that to understand what was in God's mind and why he was commanding was not the point.

Actually, the two views became mixed up, and there are several related traditions, but the great tradition was really that founded by Aristotle and usually referred to as the natural law. It posited a single law governing both the physical and the spiritual world and suggested that man could learn about one from studying the other. This set of concepts dominated the Western world and came to its greatest fruition in the person of Saint Thomas Aquinas, who, as everyone knows, developed an overarching system which put together everything in the world—physical, spiritual, and biological. Among other things it involved a much more complicated view of causality than we have as scientists. In addition to the scientific kind of causality, which Aristotle called efficient cause, great attention was paid to purpose or final cause; and there were a couple of in-between causes called material and formal causes. It is hard for us to understand exactly what was meant by each of these categories, but the big point was that people and things behaved according to some divine plan, and one could find out what the plan was by using one's reason.

It was a very satisfying view of life. It gave man a sense of a real place. Man was put here for a purpose, and all men were brothers because they were part of this grand design. (Many of us here first learned of the beauties of this way of looking at things from *Mont-Saint-Michel and Chartres* by Henry Adams, a New Englander who was not a Roman Catholic.)[7] It still provides a scheme for which even unreconstructed agnostics have a nostalgic yearning and that, perhaps, is why I am asking today if modern science can do anything to restore something like this kind of approach to normative problems.

This view of the world has largely been abandoned except in the Roman Catholic church and in certain sorts of colloquial expressions. Many of us are Aristotelians in our commonsense approach to life. For example, we will still say that nature abhors a vacuum, or that water seeks its own level, or that there is something unnatural about homosexuality. All these are Aristotelian hangovers from natural law. We no longer believe, however, that it is unnatural to charge interest for loaning money, though that was the prevailing view during the Middle Ages apparently because the nature of money was thought to be as a medium of exchange and not as a means of production. The great reason for abandoning classical natural law was that it turned out not to give good explanations of the motion of the heavenly bodies. As is well known, the pope did not like the alternative explanation put forward by Copernicus, Bruno, and Galileo, and he had even reason not to like it because the linkage between the way planets behaved and the way human beings behaved was very much closer than it is now. The whole chain of causality was thought to be the same. Thus, if one showed that the church was wrong about falling bodies, one simultaneously implied that it was wrong about the structure of society and about ethics. It was as a result, then, of the growth of modern natural science that the great edifice of natural law fell slowly to the ground. As a consequence we have lived most of this century, except for orthodox Roman Catholicism, with a view that natural law of the kind described above is obsolete. It must also be admitted that other, more practical considerations led to the decline of the tradition, not the least of these being the tendency to complacency summed up in Pope's "Whatever is, is right." Nevertheless, our nostalgia for a more coherent, unified world still drives some of us to ask if nothing can be done to revive it. If one of the reasons for its demise was the conflict between right reason on the one hand and empirical science on the other, what happens if we attempt to maintain the idea of a unified scheme but substitute what empirical science has to say about the nature and place of man for what right reason used to say? As we begin such an analysis, we would do well to bear in mind that science is at its best when it is making broad, very general statements about the nature of things. We should not expect, therefore, that it will tell us much about specific rules of behavior, such as those governing how many wives a person should have, how much intercourse he should have before marriage, or how many cigars he should smoke in a day. Indeed, one of the first results of scientific study of the human condition is to encourage a kind of ethical relativism. With a large number of different answers to specific ethical questions, it is easy to conclude that there is no universal absolute standard. But this obvious conclusion may be a little too easy.

The Nature of Man

Further consideration reveals at least a few, very broad general statements about the nature of man which appear to admit of no exceptions and which still retain some bearing on value questions. These propositions will seem absurdly simple, but they may still be worth thinking about in the present context.

The first is the very old observation that man is mortal, that he is going to die. Everybody has known this for a very long time, and it has conditioned the way man has looked at many aspects of his life. There are passages in the Bible, notably in Ecclesiastes, about the shortness of life and how this conditions what we ought to be doing and thinking. On the other hand, biology can go further than that. It can explain that death is not just some oddity that God invented for some inscrutable purpose. Science has a good explanation for death in terms of natural selection. Continuous natural selection is hard to conceive of unless the organisms that have done their part in one stage of the process get out of the way to make room for the next. Indeed, death as we know it, as a phenomenon involving individual organisms, appears in the evolutionary stream about the time that sexual reproduction and the possibility of rapid evolution also appeared. Thus genetic mixing, selection, and death are linked together. In that sense death is an integral part of the greatest creative force that we know. Therefore, we should not regret death; we should welcome it when it comes at what may be regarded as the appropriate time. For me, personally, this time appears to be about five years from now. Probably in five years it will be another five years, but in principle it is clear that man might best accept the inevitable with what dignity he can muster. Interestingly enough, cultural evolution, which has proceeded in the last ten thousand years much more rapidly than biological evolution, has incorporated the same principle. In other words, it is now recognized socially as well as biologically that people who reach a certain age should get out of the way of the young people coming up. Not only can colleges pay their young people less than they are now paying their old professors, but the young will have new ideas which will be better than those of the old and thus lead to a more rapid advancement of knowledge. This concept has not yet reached the Congress, where the effects of not having death at sixty-five are quite clear and need not be elaborated.

Thus the phenomenon of biological death antecedes and serves as a model for retirement plans in modern civilization. To me this line of thought makes both retirement and biological death more understandable and to a large extent more acceptable. Furthermore, this accepting attitude toward death in general influences one's thinking on special aspects such as euthanasia. Thus this general principle deduced from a knowledge of biology is not as trivial as it might sound at first.

The second great generalization which biology can make about man is that he is both solitary and social. There are also good reasons for this, but there is also a lot of sorrow connected with it. Much of literature and art deal with the inherent conflict between being an individual with individual longings, individual needs, and an urge for individual survival and being a member of society with social responsibilities.

Many of the biological mechanisms for individual survival under stress have been well studied and their subjective components identified. Indeed, the essential features were summarized many years ago in *Bodily Changes in Pain, Hunger, Fear and Rage,* by Walter B. Cannon.[8] The biological basis of social behavior has been much less thoroughly explored, but we are beginning to know something about it. For example, the fact that it takes us so long to grow up means that we are obligatorily dependent on our parents and surrogate parents and extended families and teachers until we reach what used to be called the age of discretion. This fact alone makes us ineluctably dependent on a social context, and it is brought home to us early in life that we must sacrifice many individual impulses in order to be accepted and supported by our society. Much emphasis is customarily placed on how much the individual must sacrifice or repress his biological needs to society's demands, but it is also possible that there is a biological drive toward cooperative or altruistic behavior. In a recent book E. O. Wilson reviews the evidence that evolution can develop altruistic feelings, impulses, or activities both in animals and in people. Wilson is convinced that altruism is in part a biological property, and he ends his discussion with a paragraph including a Hindu quotation which gives literary form to the two opposing biological drives:

> Although the theory of group selection is still rudimentary, it has already provided insights into some of the least understood and most disturbing qualities of social behavior. Above all, it predicts ambivalence as a way of life in social creatures. Like Arjuna faltering on the Field of Righteousness, the individual is forced to make imperfect choices based on irreconcilable loyalties between the "rights" and "duties" of self and those of family, tribe and other units of selection, each of which evolves its own code of honor. No wonder the human spirit is in constant turmoil. Arjuna agonized, "Restless is the mind, O Krishna, turbulent, forceful and stubborn; I think it no more easy to be controlled than is the wind."[9]

In our own culture Freud elaborated the same view in his *Civilization and Its Discontents.*[10] In the Freudian mythology the ineluctable tension between the rights of the individual and the demands of any society, civilized or uncivilized, is almost entirely interpreted in terms of sexual tension until Freud finds himself saying that the incest taboo is the greatest trauma ever done to the erotic life of man, a view which I do not share. However, the general notion that as human beings we are in an absolutely unresolvable, permanent conflict between the rights of the individual and the rights of society is, I think, beautifully laid out by Freud, and he draws an important conclusion from it—we never *will* have a perfect society.

This impossibility is important to recall because, since the Enlightenment, we have lived under the spell of the notion that there is a real possibility of a perfect society. This hope was elaborated later and perhaps most fully by Marx, but it is perfectly obvious that his followers had to abandon it even as an ideal. He and many of his followers went so far as to say that things like neurosis and personal problems of almost any kind were due to imperfections in society and would wither away as society improved. Freud was very clear, biology is very clear, Arjuna was very clear, and Wilson is very clear that the conflict between man and his social group is an inevitable thing and one out of which grow many interesting properties. Much of our art is due to attempts to resolve the conflict. Thus it is not a trivial observation that man is at the same time a solitary and a social animal.

Finally, we come to our third general statement about the nature of man, and the one most relevant for this meeting. As Bernard D. Davis has noted, men vary markedly from one another.[11] Obviously, as we look around us, we see the outward signs of variation, but we now know how to measure it quite precisely. Richard Lewontin has identified a number of substances in the blood which depend on particular gene loci, and he has estimated the number of gene loci which have the possibility of varying in man at something like 35 percent.[12] Furthermore, several different variations are available for each site. Thus there is a lot of variation in human beings. From one point of view we are much like chimpanzees. From another point of view we are not very much like one another.

Now it is perfectly obvious that this variation brings with it a great many advantages. Many of them are familiar to us and are also outlined in Wilson's book.[13] One of these is that people can work together to advantage. Since people are social and also exhibit much variation, some of them can be assigned to defense and go out to fight wars, others can stay in and write books and go into laboratories, others can dance and sing and make life more satisfactory, and others can perform what must be admitted to be less rewarding but still very necessary jobs. Since the beginning of the agricultural revolution society has exhibited a high degree of division of labor. One can argue that the preagricultural societies which show less differentiation were happier in some ways than we are and that they did not have as much social stratification of an undesirable kind, but overall production of goods and services seems to be higher in societies that maximize the skills of the most skilled people in the society. Perhaps more important for many people is the fact that variety in society lends interest and excitement to human life. Societies entirely made up of Joan Sutherlands, for example, would not have as much fun listening to music as we do because one concert would be so much like another. One also may cite the biological phenomenon known as heterosis or hybrid vigor. Offspring of very dissimilar parents may be more vigorous than those of similar parents. In more general terms, individuals with a high degree of heterozygosity may be more vigorous than those who are homozygous. Nobody quite understands why, but there seems to be an actual advantage in variation per se. Somewhat clearer is the observation that genetic variation in a society makes it more adaptable when times change. There was a celebrated controversy involving these matters between Theodosius Dobzhansky and Hermann Muller. On the whole, Muller believed that people could be made homozygous for goodness and that this would be better than having any mutations for any variation from what he thought of as an ideal norm. Dobzhansky, on the other hand, maintained that a certain amount of variation may be a good thing, and he based his view on observations of *Drosophila* colonies in the wild.[14] The ones which had more variation seemed to have a greater viability and life expectancy than those that were homogenous, presumably because the latter encountered more difficulty in changing when conditions changed.

There are thus many reasons, both biological and social, to believe that there are advantages in human variation. There are also obvious and painful disadvantages. Human variation raises awkward questions of distributive justice. It is customary to say that only the brave deserve the fair, but is that fair? Is God only on the side of the strongest battalion? Are some men born to be slaves, as Aristotle thought and some later followers of the natural law tradition believed? Are material goods the outward and visible signs of inward and spiritual grace? Should each one be rewarded according to his ability? Or should we take the Marxian view and give to each person what he needs and take from each person what he is able to give? Nature does not give any very obvious answers to these questions. It appears rather impersonal, and how anyone could have extracted the idea of distributive justice from studying the biological world is hard to see. Nature distributes her favors in a very irregular and arbitrary way. Indeed, this apparent lack of natural justice has caused a good deal of trouble for conventionally religious people from the very beginning. How could an all-wise, all-loving, all-just God distribute the tangible goods of this world so unjustly? This was one of the very great theological puzzles.

Concerning one aspect of this problem, Milton in *Samson Agonistes* intoned, "Just are the ways of God and justifiable to man." He was talking about retributive justice and not distributive justice, and I think that most of the cases involving justice in the Bible deal with retributive rather than distributive justice. Aristotle and the Greeks were concerned with both types, but the God of the Old Testament was an avenging Jehovah who provided retribution to those who broke his laws. In that same sense one does see a kind of retributive justice in nature. There are certain laws that cannot be broken without running into trouble. If one drinks bad water, one is likely to get sick, or if one runs around with women too much, one is likely to get venereal disease. This is a natural retribution, if you will. But the distributive sort of justice is harder to find in either biology or divinity. Human beings themselves seem to have invented the idea of equal treatment, including the notion of some approach to an equal or at least just distribution of goods. It is certainly a splendid concept even if we do not yet know how to implement it.

Controversies about Human Variation

It is obvious that the phenomenon of human variation, which has many advantages, has led to problems about which there are very significant controversies. The significance of the nature-nurture differences seems to me to have been greatly exaggerated as a policy matter. We can begin our discussion by asking ourselves why people feel so strongly about this matter. Apparently, there is a feeling that genetic differences are in some way harder to change than environmental ones, but I hope to give some evidence that this may not be entirely true. Certainly, genetic differences have also been used in the past to justify differential treatment. And the same idea has been used in another sort of context to justify devil-take-the-hindmost, laissez-faire economics. But these attitudes now seem to most observers to result from a too simple reading of the genetic lesson.

On the other side of the street there has been a belief that environmental effects are easy to change and easy to improve and that man is, in fact, perfectible through environmental manipulation. This type of thinking, among other things, motivated the anarchists of the last century and the queer, little revival of anarchism that we have had in our colleges during the sixties.

In fact, however, there seems to be no reason for presuming that genetic defects are more permanent or harder to correct than environmental ones. Some are and some are not, and, as far as I know, nobody has counted them up on either side or tried to provide a numerical answer. Furthermore, the pattern is constantly changing as we learn more about both kinds of influence. As an example of a genetic deficiency which is not difficult to correct or compensate, one may cite civilized man's loss of precise temperature control. The Australian aborigines are said to lie out on the plains of Australia with the temperature below freezing and to suffer little inconvenience. We here obviously have lost the gene that would have given us an automatic fur coat. On the other hand, we have learned how to light fires, and, as long as the Arabs will sell us oil, we can make up for our genetic defects by keeping our houses warm and by wearing warm clothes. To cite another more specific example, we are unable, as human beings, to synthesize vitamin C. It is not a very difficult chemical synthesis. Rats do it without trouble, and so do a good many other species. We do not regard our deficiency as a disease or an embarrassing defect, however. We simply drink orange juice every morning. There are many similar deficiencies that are shared by all human beings and that can be compensated similarly.

Next we come to another class of genetic defects or omissions or commissions which affect only part of the human race. One of these is diabetes. We are not quite clear about how diabetes is inherited, but it is obvious that it runs in families and in some racial groups more frequently than it does in others. We are able to compensate for this to a large extent, though not completely, by giving people insulin and by adjusting their diets. We have already heard about phenylketonuria, a disease which if left untreated always produces some degree of mental defect. If, from birth, the affected children are put on a diet which is low in phenylalanine, a very considerable number of them develop normally enough so that they get along as independent human beings. Quite recently, a dominant gene that is responsible for very high blood cholesterol and blood lipids and thus leads to atherosclerosis early in life has been identified. People homozygous for this condition usually have cholesterol deposits in their skin during their early teens, and most of them die of heart disease at early ages. Most of the heterozygotes will have a heart attack by the time they are sixty. It remains to be seen how much we can compensate for this condition by diet, but the situation is far from hopeless. Thus we can describe a series of genetic defects, some of which can be totally compensated for, others like diabetes which can be partially compensated for, and still others such as atherosclerosis where the interplay between genes and environmental compensation remains to be worked out.

On the other hand, I can think of a number of environmental problems which are impossible to do anything about. In this case, for example, we must place severe physical trauma. A broken neck results in a paraplegia, and there is nothing we can do about it. The spinal cord does not regenerate; we know of no way of helping it to regenerate; and thus a person is permanently crippled if he breaks his neck. Another sort of environmental effect which may produce lasting damages is neonatal or perinatal anoxia, or insufficient supply of oxygen to the fetus during the latter moments of pregnancy and the first moments of life. This is probably responsible for a very considerable proportion of the so-called mental retardation in this country, a good part of the spastic paralysis, and so on. Relief of these conditions has so far been rather less successful than that of many genetic errors. Severe early dietary deprivation has been mentioned as a possible cause of mental retardation. Fortunately, it is not very common, but, when it does occur in severe form, it seems to be largely irreversible. In former times many of the infectious diseases like poliomyelitis or scarlet fever left their victims with various degrees of permanent crippling.

In between the clear-cut genetic disorders on the one hand and clear-cut environmental problems on the other are a variety of disorders where both factors play important roles. The major psychoses have a very important genetic component—so important that many students of the subject probably would say that one cannot get schizophrenia or manic-depressive disorder unless one has the appropriate genes. However, by no means does everyone who has the genes get the disease. Thus environmental influences can control the appearance of what is basically a genetic disorder.[15] Even after the disorder has expressed itself, it is possible to reduce greatly its severity by proper use of drugs, proper environmental stimuli, and so forth. Perhaps the most dramatic recent improvement in the environmental treatment of a genetic disorder is found in manic-depressive disease, where the manic phase can be controlled by giving a lithium salt. These examples should be sufficient to demonstrate that, even if we can determine whether a given trait is primarily genetic or primarily environmental, such information gives no a priori reason for predicting how easy it will be to correct.

Now let me say just a few things about how genetic and environmental facts interact to produce the final organism. Davis mentions in passing that it is very hard to untangle the two from each other.[16] But I am not sure that he emphasizes how very hard it is in many practical situations. We are simply not at all clear about what it is that decides whether, in fact, a gene will be transcribed into a given characteristic or not. Lots of genes are born to blush unseen at least until adolescence, and they may be unseen even for life. Perhaps only half the people who carry the genes for schizophrenia actually develop it. Even some scientists have tended to forget the importance of developmental influences in their boyish enthusiasm about the double helix. Many are so delighted with the double helix and the four-letter code that they forget that in actual practice these things do nothing at all unless something else happens, and it is not easy in any given case to determine what the something else is. To cite a familiar and homely example, most seeds will not germinate unless provided with the right temperature and humidity. In most of the higher animals the genetic apparatus that determines the adult form of the reproductive apparatus remains dormant for years until it is released by a combination of unknown and sometimes known factors, such as temperature, relative day-night lengths, nutritional state, and so on.

Painstaking study of development in laboratory animals suggests how complex the interactions may be. The administration of particular hormones or the withholding of critical vitamins at specified, surprisingly brief periods during pregnancy can result in gross failures of development, including such familiar conditions as cleft palate, hydrocephalus, or deformed extremities. But the expression of these environmental influences varies enormously with the genetic strain of the animals used. Some may be almost immune to a given agent. In other strains nearly all the animals may exhibit severe malformations.[17] In the face of this kind of interaction it is hard to think of a formula which can give a precise percentage figure for the degree of hereditary and environmental influences in the production of the defect. In a population on an adequate diet the defect would simply not appear, and no genetic influence could be identified or reported. In a population on a uniformly bad diet the appearance of the defect would appear to be completely genetically controlled. Somewhat the same kind of intricate interaction is illustrated by, for example, the learning of songs by meadowlarks. The meadowlark tends to sing a particular song. If it is raised by hand so that it does not hear the song from its parents, when it gets to a certain age it begins to sing a song in the usual way. But the song is not a very good meadowlark song. If, however, the bird is exposed just once to an older bird who sings the proper meadowlark song in a proper dialect, the young bird will sing it properly for the rest of his life. However, if it is not exposed at the right time, it never learns to sing correctly. Clearly, there is a very intimate interplay between heredity and environment in the development of this particular, very necessary talent of meadowlarks, and it does not make much sense to ask which is more important. Both are essential.

In summary, then, the whole business of nature-nurture is so complicated that I for one have difficulty drawing a precise policy conclusion in any controversy involving it. It may be that the only important thing is to study ways of retraining or especially educating people who seem in one way or another to be not as competent as other people. Surely, we could release a lot of energy for this purpose if we stopped arguing about the precise causes of slow learning and turned our attention to finding out what we could do about it.

I should mention in passing, because it does represent one important extreme, Lewontin's point of view. Lewontin has probably done more than any other person to demonstrate the degree of variation there is among human beings. But he has also taken the view that we have now evolved so far that we transcend our genetic determination, so to speak. Everyone more or less agrees that man has evolved toward a greater and greater plasticity of the nervous system. In other words, fewer and fewer of man's adaptive behavioral responses are built in such a way that they cannot be changed. Social insects behave the way they do because they have a preprogrammed nervous system. A drone is a drone is a drone, and a queen is a queen is a queen, and a worker is a worker is a worker. The habits, the things that they do, the responses, all are laid down beforehand in their nervous systems.

The significant thing about man, Julian Huxley once said, is that his nervous system is specialized for unspecialized behavior. As a result, man can do all kinds of different things, and that is why he can live in all kinds of different climates and develop all sorts of different tools and all different sorts of sexual behavior. This is also what makes his conflict with society particularly poignant and why civilization with its discontents is even worse for man than it is for other social species —because man knows he has choice. The very fact that his nervous system and his behavior are so plastic means that he can choose between various types of social behavior, or he can choose to be selfish, and so on, and the conflict becomes conscious.

Lewontin would go so far as to say that our brains have become so plastic that there is no genetic tendency or capacity in any particular direction. Everything the adult human being does has been essentially learned during his lifetime. This view, as I understand it, really brings us back to an exaggerated form of Locke's so-called tabula rasa, which was also the fundamental background of the school known as behaviorism. Perhaps the most vigorous protagonist of behaviorism, John Watson said, "Give me ten children at the age of two days or whatever and I will make one into a secretary and one into the president of the United States and one into a female Mozart . . . ," or words to that effect. He never actually did so—there has been no female Mozart. But at least the possibility has been thought of, and Lewontin is the most creative and the most generally recognized population geneticist who takes this view. Obviously, Davis and I do not take this view, and neither does Wilson.

I would like now to shift gears and talk about what can be done about extreme variations which almost everyone would regard as undesirable. In other words, what is the modern attitude toward what used to be called eugenics? Obviously, we will be very much more cautious about defining an undesirable characteristic than our ancestors were, partly because we have been through some experiences that our ancestors did not have, and partly because we are beginning to realize that genes which in some contexts are "bad" are good in other contexts. The classic example (Lewontin says the only example) is sickle-cell anemia. In this condition the heterozygotes, who have two genes one of which makes sickle cell while the other makes normal hemoglobin, are partially protected in infancy against cerebral malaria. As a result this gene is very frequent in those areas of West Africa that have severe falciparum malaria. It is a good gene to have there. The only difficulty with it is that if both genes are abnormal the subject suffers from a very severe form of anemia and usually dies in infancy under African conditions.

Now we in this country do not have cerebral malaria or, indeed, malaria of any kind. Thus approximately 10 percent of our population that carry one gene for sickling have nothing to be protected against, and the homozygotes still have the anemia. So here we have a gene which most of us would have to regard as good in West Africa but which is clearly bad over here. This kind of phenomenon leads us to be cautious about identifying bad genes and trying to get rid of them through a eugenics program.

In spite of the caution engendered by increasing awareness of the possible advantages of certain, apparently deleterious genes, there still are some conditions that are so uniformly undesirable as to justify some effort to control their appearance. Already mentioned are some chromosomal abnormalities which can be identified in utero in time to allow aborting the fetus. Fortunately, these chromosomal abnormalities are not very frequent. Of more consequence are the differences which can be attributed to mutant genes. Approximately two thousand such differences have so far been identified. Some of these are very serious or even fatal. Others are marked by little or no disturbance of function. The great majority lies somewhere in between. Most identifiable, deleterious genes are fortunately quite rare. So far many have been reported as having caused only a few cases of disease.

As is well known, there have been times in the past when it was thought possible and desirable to regulate human breeding so as to reduce undesirable characteristics and increase desirable ones. For several reasons such so-called eugenics movements are now generally discredited. All that remains is an interest in reducing the appearance of severe, clearly undesirable degrees of variation. In practice this means a relatively small number of conditions caused by single genes or chromosomal abnormalities and an even smaller number of very severe conditions of as yet undetermined origin, such as anencephaly and spina bifida. This kind of eugenic decision lies almost completely in the hands of prospective parents and their physicians, although, of course, they are free to take into account the broader social implication of their reproductive decisions. Typically, parents consult a physician or counselor because they have already had one defective child or are afraid they may have one because of their family history. This is not the time or place for a detailed technical discussion, but usually the counselor is able to give some figure for the probability that any child the couple may have may be defective. Depending on the nature of the condition, he can then list the options available for avoiding or sharply reducing the risk. The first procedure, of course, is simply to avoid having any children. Another is artificial insemination from a donor who is not a carrier. Yet another, which may become available in the next few years, is to obtain an egg from a normal donor, fertilize it with the husband's sperm, and implant the fertilized ovum in the wife's uterus. Finally, in an increasing number of cases, it is possible to allow the wife to become pregnant in the normal way and then to utilize the procedure of amniocentesis to test the fetus to see if it is actually suffering from the suspected defect or disorder. In this case, unless religious or philosophical scruples intervene, abortion can be offered and the couple encouraged to try again. In this connection it may be recalled that in the case of dominant genes the chance of having an affected child is one in two. For recessive conditions, it is one in four. The probabilities for the identifiable chromosomal errors are usually much more favorable. In an increasing number of instances amniocentesis and abortion provide a way for couples carrying known genetic defects to have normal families at the cost of only very modest interference with normal patterns of reproduction. Improvements in the prenatal identification of serious genetic errors hold out the hope, at least in principle, of avoiding their appearance almost entirely. But the statement applies only to those conditions at the extreme end of the distribution curve. There is no known way short of intensive inbreeding of reducing what might be called the normal (still very wide) range of human variation, and we almost certainly should not do that even if we could. Thus we are left with the necessity of dealing with the social and individual consequences of variation.

Clearly, human variation reflects very basic biological principles which lie at the root of the whole evolutionary process. There are also reasons for welcoming variation here and now for its contribution to a more interesting and productive society. On the other hand, variation leads to tensions of various kinds. Not the least of these is the fact that in most societies some types and degrees of variation are better rewarded than others. Almost all societies try to compensate for this inequitable distribution of natural capacities and the attendant inequitable distribution of goods, but none has been strikingly successful. It remains a major challenge to future societies to find ways of maximizing the social advantages of human variation while minimizing its obvious disadvantages.

NOTES

1. David Hume, *A Treatise on Human Nature* (1886; reprint ed., Aalen: Scientia Verlag, 1964).
2. Antony Flew, *Evolutionary Ethics* (London: Macmillan Co., 1967).
3. Max Weber, "The Meaning of 'Ethical Neutrality' in Sociology and Economics," in *Max Weber on the Methodology of the Social Sciences,* ed. and trans. Edward A. Shils and Henry A. Finch (Glencoe, Ill.: Free Press, 1949).
4. Andrew D. White, *A History of the Warfare of Science with Theology in Christendom* (New York: Free Press, 1965).
5. Henry K. Beecher, "Ethics and Clinical Research," *New England Journal of Medicine* 274 (1966): 1354–60.
6. C. P. Snow, *The Two Cultures and the Scientific Revolution* (New York: Cambridge University Press, 1964).
7. Henry Adams, *Mont-Saint-Michel and Chartres* (Boston: Houghton Mifflin Co., 1905).
8. Walter B. Cannon, *Bodily Changes in Pain, Hunger, Fear and Rage: An Account of Recent Researches into the Function of Emotional Excitement* (New York: D. Appleton & Co., 1915).
9. E. O. Wilson, *Sociobiology* (Cambridge, Mass.: Harvard University Press, 1975), p. 129.
10. Sigmund Freud, *Civilization and Its Discontents* (London: Hogarth Press, 1930).
11. Bernard D. Davis, "Evolution, Human Diversity, and Society," in this issue.
12. Richard Lewontin, *Genetic Basis of Evolutionary Change* (New York: Columbia University Press, 1974).
13. See n. 9 above.
14. Theodosius Dobzhansky, *Heredity and the Nature of Man* (New York: Harcourt, Brace & World, 1964).
15. Paul B. Beeson and Walsh McDermott, eds., *Cecil-Loeb Textbook of Medicine,* 13th ed. (Philadelphia: W. B. Saunders Co., 1971).
16. See n. 11 above.
17. James G. Wilson and Josef Warkany, eds., *Teratology: Principles and Techniques* (Chicago: University of Chicago Press, 1965).