Genetic Diversity & Human Equality

The Facts & Fallacies in the Explosive Genetics & Education Controversy

Theodosius Dobzhansky

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Theodosius Dobzhansky, until his recent death, was acknowledged as one of the world's greatest geneticists. He was for twenty-two years (1940-1962) Professor of Zoology at Columbia University, and taught at the Rockefeller Institute from 1962-1971. His works include *Genetics and the Origin of Species* (1937), *Genetics and the Evolutionary Process* (1971), *Heredity and the Nature of Man* (1964), and *Mankind Evolving* (1962).

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FOREWORD BY

Ward Madden

CHAIRMAN, COMMISSION ON LECTURES, THE JOHN DEWEY SOCIETY FOR THE STUDY OF EDUCATION AND CULTURE

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FOREWORD

How is one to account for the fifteen or so points that separate the average scores of whites and blacks on conventional intelligence tests? And what is the meaning of the twenty-eight-point differential between the children of professional men and the children of unskilled workers? The standard answer of those with faith in the worth of the individual and the equality of men is that these differences are to be accounted for by environmental influences.

But some disturbing facts intrude. Why is it that identical twins reared together show an 87 percent correlation with one another in IQ, whereas unrelated children reared together show only a 24 percent correlation? Why do such twins, even when reared separately, still show a 75 percent correlation, whereas unrelated children reared separately show no correlation at all? Such studies seem to suggest that, even though the environment matters, its influence is heavily outweighed by genetic factors.

Various investigators, most recently Arthur R. Jensen in 1969, have concluded that intelligence is determined approximately 80 percent by heredity and only 20 percent by environment. This conclusion has encouraged the doubts existing in the minds of some that the children of the poor have the necessary genetic equipment to rise, in numbers proportional to their population, to higher positions in society. And it has supported, in some, doubts about the "inherent" ability of black Americans.

These questions are rarely discussed openly—but there is an insidious effect in the taboo itself. In the silence, the suspicion persists that not only may intelligence be more determined by genetics than by environment but also—what is especially disturbing—intelligence may be unequally distributed among the social classes and races.

Here and there, of late, there have been isolated calls that the whole question be reopened, and that a strong new effort be made in the objective spirit of science to ascertain and to understand in all its complexity the actual situation. It has been suggested that in the past the question has actually been neglected by serious researchers because of conscious and unconscious prohibitions in the collective and individual minds of scientists—generated by laudable but nevertheless misguided liberal-humanistic presuppositions.

Theodosius Dobzhansky agrees that more needs to be known. The subject should not—need not—be taboo, he says. And he shows us that a truly sophisticated analysis and interpretation of scientific evidence points toward conclusions quite different from those that currently seem to threaten the widely shared hope for a just and equal society.

Dr. Dobzhansky's work makes clear, as never before, that there is no conflict between our democratic social goals and the findings of science. We need not fear the truth. Science has never inhibited men from realizing their ethical objectives, nor does it now. Only our own ignorance of the truth can frighten us into abandoning justice. Dr. Dobzhansky's brilliant little book lucidly explains where scientific research leaves off and where the realm of moral choice begins. It should be required reading for all Americans.

Ward Madden

PREFACE

JOHN DEWEY THOUGHT that philosophy should be more than an academic vocation or a demonstration of intellectual gymnastics: "There is probably no better way to realize what philosophy is all about when it is living, not antiquarian, than to ask ourselves what criteria and what aims and ideals should control our educational policies and undertakings." The same standard applies, I believe, to evolutionary biology. Although a biologist may do his research on mice, Drosophila flies, plants, or bacteria, the ultimate aim should be to contribute toward the understanding of man and his place in the universe. Biology, and science as a whole, should be anthropocentric, i.e., relevant to man. The "relevance" goes deeper than technological, environmental, and other so-called practical problems. Basic or fundamental science is a humanistic enterprise. Dewey rightly regarded separation of science from ethics and values "intellectual scandal." He was one of those who believed (in the words of Martin E. Malia) "that the life of the intellect yields not only scientific truth, but moral truth; that the moral truth is also inevitably social in nature; that there exists, therefore, in scientific and rational politics the aim of which is social justice, or equality; and that the men of intellect, by definition, are the chief bearers of this truth-which-is-justice." Cynics say that people use science merely to give a veneer of respectability to their selfish interests and bigotries. There is no denying that science is sometimes so used. Yet human conduct is also influenced by the beliefs that men hold, and science is increasingly important as a source of these beliefs. In particular, evolutionary biology is relevant to "aims and ideals" of "educational policies and undertakings."

The first two chapters of this book are parts of a single essay; a version of the first was given as the John Dewey Lecture on February 25, 1972, in Chicago, while a version of the second has been published in *Sexual Selection and the Descent of Man,* edited by Bernard G. Campbell (Aldine • Atherton, Inc., Chicago). The third chapter has been published in *Changing Perspectives on Man,* edited by Ben Rothblatt (University of Chicago Press). Thanks are due to the above publishers for permission to utilize these chapters in the present book. I wish also to express my gratitude to Professor Ward Madden and to the officers of the John Dewey Society for the honor of having been chosen a John Dewey Lecturer.

Theodosius Dobzhansky

CONTENTS

GENETIC DIVERSITY AND HUMAN EQUALITY

1

DIVERSITY OF INDIVIDUALS, EQUALITY OF PERSONS

WIDESPREAD IN THE MODERN WORLD, though by no means universally accepted and practiced, is the doctrine that all men are or should be equals. Forcefully stated in the ringing sentences of the Declaration of Independence, it is familiar to every American. The idea of equality is an integral part of the American tradition, and also the source of what Myrdal (1962) called the American Dilemma. The idea frequently bogs down in confusion and apparent contradictions. Equality is confused with identity, and diversity with inequality. This confusion can be found even in the writings of some outstanding scientists who could have been expected to know better. Political propagandists, of both the extreme right and left, spread the confusion deliberately.

It would seem that the easiest way to discredit the idea of equality is to show that people are innately, genetically, and therefore irremediably diverse and unlike. The snare is, of course, that human equality pertains to the rights and to the sacredness of life of every human being, not to bodily or even mental characteristics. According to the 1952 UNESCO statement on race, "equality of opportunity and equality in law in no way depend, as ethical principles, upon the assertion that human beings are in fact equal in endowment."

Defenders of equality become entangled in the same snare when they attempt to minimize or deny human genetic diversity. They overlook, or fail to understand, that the diversity is an observable fact of nature, while equality is an ethical commandment. At least in principle, equality can be withheld from, or bestowed upon, members of a society or citizens of a state regardless of how similar or diverse they are. Inequality is also not biologically given but is rather a socially imposed prescription.

The Source of Genetic Diversity

Everyday experience shows that every person we meet is different from everybody met before. Even so-called identical, or monozygotic, twins are not really identical; they are recognizably separate persons. The recognition of individuality is a generalization derived from common practice, but the causes of individuality began to be understood only with the advent of biology, and particularly genetics. Mendel showed that parents heterozygous for the same n genes have the potentiality of producing 3^n genetically distinct kinds of progeny. Parents each of whom is heterozygous for n different genes are potentially capable of producing 4^n kinds of progeny. The question of the number of genes for which an average person is heterozygous has long been a matter of speculation and dispute. It now appears that the figure is at least in the thousands or ten thousands. Even though not all possible genetic endowments are equally probable, the genetic variety engendered in sexual reproduction is immense. Excepting only monozygotic twins and other monozygotic multiple births, the likelihood that any two persons alive, or having lived, or to live in the future, will be genetically identical is negligible. The source of the genetic variety is Mendelian recombination of genes in sexual reproduction; monozygotic multiple births result from asexual multiplication of sexually produced fertilized egg cells.

Human individuality manifests itself in all sorts of characteristics. Perhaps one of the most imposing examples is the rejection of skin grafts or organ transplants derived from other persons. Homografts, i.e., skin transplants from one part to another of the same person's body, are usually accepted without difficulty, as are transplants from one monozygotic twin to another. But a graft from another person, even a sibling, parent, or child, is usually rejected because of an immune reaction in the recipient. Only by rather drastic measures involving artificial suppression of antibody production in the recipient is it possible to have transplants derived from other persons, or even different species, temporarily adopted. For obvious reasons, these matters have been studied in greatest detail in experimental animals, namely mice. The studies have revealed numerous so-called histocompatibility genes; only if two individuals happen to carry the same forms (alleles) of these genes can allografts (transplants from one individual to another) be successful. Apart from monozygotic twins, such genetic similarity may occur among members of an inbred line, propagated for many generations by mating close relatives, usually brothers and sisters. Because of the universality of incest taboos in man, prolonged inbreeding of this sort is not found in human populations.

Genetic individuality in man and other sexually reproducing species is also demonstrable by examination of some biochemical characteristics. The existence of a variety of blood groups, recondite but important differences of the red blood cells which must be guarded against in blood transfusions, has been known since early in the current century. More recently, genetically determined variants of some enzymes (allozymes) have attracted attention. Studies on several species of Drosophila flies have shown that an average individual in natural populations is heterozygous for between 10 and 20 percent of the genes determining allozyme variants. A similar situation appears to prevail in human populations. It is not certain that the allozyme genes studied are a fair sample of all genes possessed by an organism. The number of genes in a human sex cell is also not known—recent estimates range from a hundred thousand to several million. However, taking the figures of 10 to 20 percent of heterozygous genes at face value, the number of potentially possible gene constellations turns out to be far greater than the number of subatomic particles estimated by physicists to exist in the whole universe. One inevitable conclusion is that only a minute fraction of possible genetic endowments can ever appear in the human or any other biological species.

Whether the genetic diversity of allozyme variants, or of histocompatibility genes, is of much significance socially may, of course, be questioned. At first thought, the answer seems to be negative. With the exception of some pathological variants, one's form of enzyme or of blood groups seems to make no difference. However, genes may have so-called pleiotropic effects, and modify several characteristics. Thus, many hereditary diseases caused by changes in single genes are "syndromes" of seemingly quite unrelated characteristics. One cannot rule out the possibility that apparently neutral, neither useful nor harmful, genetic variants may have unsuspected concomitants in the physiological and mental sphere. For example, it has been claimed that the B, A, and O blood groups are related to resistance to plague, smallpox, and syphilis, respectively. The validity of this claim is still under scrutiny.

Genes and Environments

Genetic conditioning of many human traits that unquestionably matter to their possessors and to the societies in which they occur is established with varying degrees of certainty for different traits. The word "conditioning," instead of "determination," is here used advisedly. Intelligence, personality, special abilities, and other traits are susceptible to modification by genetic as well as environmental factors. What, then, is the meaning of the often-heard statement that the intelligence of a person is determined by his genes? It certainly does not mean that a possessor of these genes must necessarily have this and no other degree or kind of intelligence, because the same gene constellation could have resulted in either a higher or a lower intelligence in different circumstances. The genes have *determined* the intelligence (or stature or weight) of a person only in the particular sequence of environments to which that person has been exposed in his upbringing and life experiences. What actually develops is *conditioned* by the interplay of the genes with the environments. Every person is unique and nonrecurrent. No two individuals, except monozygotic twins, have the same genes; not even monozygotic twins have the same environment.

Now let us consider people in general rather than a particular person. What the genes really determine are the reaction ranges exhibited by individuals with more or less similar genes over the entire gamut of possible environments. The concept of reaction range is important, and is curiously difficult for some people to grasp. Heredity is not a status but a process. Genetic traits are not preformed in the sex cells, but emerge in the course of development, when potentialities determined by the genes are realized in the process of development in certain environments. Similar genes may have different effects in dissimilar environments, and so may dissimilar genes in similar environments.

Although it is often said that the genes determine the upper and the lower limits which a trait, such as intelligence or stature, can reach, this is not a useful formulation. Existing environments are endlessly variable, and new ones are constantly added. To test the reactions of a given gene constellation (or a cluster of kindred ones) in all environments is obviously impossible. For example, how could one discover the highest stature that I could have reached in some very propitious environment, or the lowest one at which I could have stopped growing and still remained alive? It is even more farfetched to forecast the stature in environments that may be engineered in the future, perhaps with the aid of some new growth hormone.

The idea that intelligence and other socially significant human traits may be hereditary is repugnant to many people, largely because of confusion of heredity with fate or predestination. A genetic conditioning of the variations in intelligence does not necessarily mean that the intelligence of a person is irremediably fixed by his genes. It can be enhanced or stunted by upbringing, training, and disease. In principle, any trait is subject to modification by genetic as well as environmental means. The more that is known about the developmental physiology of a trait, the greater is the feasibility of influencing it in directions that are regarded as desirable.

Suppose, for the sake of argument, that the average intelligence of representatives of some class or race is higher or lower than the averages for other classes or races in the environments that exist at present in our society. Would this justify race and class prejudice? Not at all, because even with our present pitifully inadequate knowledge, important changes in manifested intelligence can be induced by intensive care and tutoring of children (Heber, 1968). With altered rearing and educational environments, the disparity of group averages may conceivably be nullified or reversed. One often hears that those who give credence to developmental flexibility of human traits fear that studies on class and race averages might disclose the dreadful fact that these averages are genetically conditioned. Such fears can be experienced only by those who misunderstand the nature of genetic conditioning.

We need to ascertain the reaction repertories of the available variety of human genetic endowments in existing and feasible physical, nutritional, educational, and social environments. The importance of research in this field can hardly be overestimated. Yet the knowledge of which environments are most propitious for realization of socially desirable potentialities of human genetic endowments remains inadequate, despite some spectacular achievements of educational and medical research. Agricultural research is in principle a similar endeavor applied to domesticated animals and cultivated plants. But an agriculturist can at present go further than a sociologist, and can intervene to modify the genetic constitutions of the animals and plants concerned. The modification is directed toward making them develop in the environments in which they are placed in ways most advantageous to man. Analogous intervention in man's development is envisaged by various eugenical programs, but this is a task largely for the future. In any case, genetic conditioning, no matter how strong, does not preclude improvement by manipulation of the environments.

Genetic and Environmental Conditioning of IQ

By far the most abundant information on the distribution and genetics of any mental trait in man is that on the intelligence quotient (IQ). There is nevertheless much uncertainty, and inconclusive polemics, as to the precise nature of the "intelligence" that the IQ measures. I do not intend to masquerade as a psychologist, and for orientation in the problems in this field must refer the reader to the works of Anastasi (1958), Brown (1965), Butcher (1968), Thomson (1967), Tyler (1965), and references therein. My excuse for intruding on this domain is that recent sensational and inflammatory pronouncements about the genetics of IQ differences between socioeconomic classes and races have attracted public attention. A critical consideration of the genetic aspects of the situation is in order.

No competent scientist takes the IQ as a measure of overall quality or worth of human beings (although a part of the public has been misled into believing this). The possessor of a high IQ may be vicious, selfish, lazy, and slovenly, and a lower IQ may be combined with kindness, altruism, and hard and careful work. Burt (1961) is one of those who claim that "we may safely assert that the innate amount of potential ability with which a child is endowed at birth sets an upper limit to what he can possibly achieve at school or in afterlife," and that IQ measures this supposedly innate ability. Others deny that IQ testing provides any scientifically valid information, and see in it merely a device used by the privileged classes to maintain their status at the expense of the underprivileged ones. It is unfortunate that the writings of Jensen (1969), Eysenck (1971), and some others are eagerly exploited by racist propagandists, perhaps without consent of the scientific investigators themselves.

The extravagant claims and counterclaims should not preclude a rational view of the issue. The warrant for IQ testing is simply its statistical predictive power. Even though just what mental and psychophysiological traits are included in the IQ scores is not conclusively established, it is undeniable that there are significant statistical correlations among IQ scores, success in schooling, advancement in the occupational structure as at present organized, and, at some removes, prestige and pecuniary rewards meted out in western capitalist or "postindustrial" societies. It is important to keep in mind that, since the correlations are not perfect, the IQ does not forecast reliably the achievement of an individual tested. The predictive power may also be limited in societies structured very differently from ours, such as Chairman Mao's China or that of the Kalahari Bushmen.

That differences between individuals in whatever qualities the IQ tests measure are genetically as well as environmentally conditioned is now securely established. Since the IQ is correlated with scholastic achievement, the latter is also, though to a lesser extent, genetically and environmentally conditioned. Evidence of genetic conditioning is ample; it comes from more than 50 independent studies in 8 different countries, and comprises more than 30,000 correlational pairings. It has been carefully and critically summarized in a brief article by Erlenmeyer-Kimling and Jarvik (1963), and in more detailed form by Jensen (1969). Median correlation coefficients obtained are shown in Table 1–1.

In the human species more than in any other, relatives "inherit" similar genes as well as similar environments. Therefore, a close resemblance of monozygotic twins to each other would not by itself demonstrate that IQ is under genetic control. However, the fact that the resemblance of monozygotics is appreciably greater than the resemblance among dizygotics makes this irrefutable. To be sure, the objection has been raised that since parents, playmates, teachers, and so on, treat monozygotic twins more alike than they do dizygotic ones, the environments of the former are more similar than those of the latter. But this is a misapprehension.

TABLE 1–1

Median correlation coefficients between IQs of persons of different degrees of relationship (after Spuhler and Lindzey, 1967; and Jensen, 1969).

Relationship	Number of of Studies	Median Correlation
Twins, monozygotic, reared together	14	+0.87
Twins, monozygotic, reared apart	4	+0.75
Twins, dizygotic, same sex	11	+0.56
Twins, dizygotic, different sex	9	+0.49
Siblings, reared together	36	+0.55
Siblings, reared apart	33	+0.47
Parent and child	13	+0.50
Grandparent and grandchild	3	+0.27
First cousins	3	+0.26
Unrelated children, reared together	5	+0.24
Unrelated children, reared apart	4	−0.01
Foster parent and child	3	+0.20

Parents and other people rarely know for sure whether a given pair of twins are mono- or dizygotic. The greater similarity of the environments of monozygotic twins is a consequence of their genetic similarity. Genetics and environment in man are covariant.

The IQs of monozygotic twins reared together are correlated more strongly than they are in those reared apart. This is obviously a matter of environment. Yet the monozygotics reared apart remain more similar on the average than dizygotics reared together. This is a matter of genetics. The correlations observed between dizygotic twins, siblings, and children reared by their parents fall between + 0.47 and + 0.56. Since all these categories of relatives share on the average the same proportions of genes, 50 percent, we have further evidence of genetic conditioning. Grandparents and grandchildren have on the average 25 percent of the genes in common, and the intercorrelations between them are correspondingly reduced. Most impressive evidence, despite some possible biases in the data, comes from testing adopted children along with their adoptive or foster parents and their biological parents. Adopted children evidently have genes in common with the biological, but share the environments with the adoptive parents. However, their IQs correlate more closely with the biological than with the adoptive parents. Siblings reared together are more similar than unrelated children reared together, just as the latter are more similar than unrelated children reared apart.

It is important to realize the meaning as well as the limitations of the above evidence. Almost all of it comes from studies on Caucasian and predominantly middle-class people (an exception is Vandenberg, 1970, who studied some black twins). Neither the twins, nor siblings reared apart, nor adopted children, have been exposed to the full range of environments which occur in the societies in which they live, not to speak of mankind as a whole. It can be seen in Table 1–1 that the IQs of monozygotic twins reared apart remain considerably more similar than those of dizygotic twins, and siblings reared apart are more similar than unrelated children reared together. How far the observed correlations could be lowered by greater environmental heterogeneity remains an open problem, although no conceivable heterogeneity is likely to reduce it to zero.

The work of Heber (1968) has already been mentioned. It describes an experiment on ghetto children whose mothers had IQs below 70. Some of these children received special care and training, while others were a control group. Four years after the training period the IQs of the former averaged 127 and those of the latter 90, a spectacular difference of 37 points. The fact that the control children had a 20-point advantage over their mothers is not unexpected. The IQs of their fathers are unknown, but may have been considerably above those of the mothers. Furthermore, such an advantage could come from the well-known genetic phenomenon of regression toward the mean: the progeny of parents above the population mean do not on the average attain the parental values, while those with parents below the population mean generally exceed the parental values. Regression toward the mean is observed with all sorts of traits, such as stature and body proportions, and it is only natural to find it with IQs.

The work of Skodak and Skeels (1949) is equally impressive. They studied the correlations between the IQs of adopted children and those of their biological and adoptive mothers, finding the latter correlations lower than the former. This does not mean that the IQ values of these children were like those of their biological parents. They were substantially higher (106 in children, 85.5 in their mothers), although not attaining the average levels of the adoptive parents or the biological offspring of the latter. This yields a simple conclusion: the genetic conditioning of IQs does not make them impervious to environmental modification.

The Heritability Controversy

Human stature varies from giant to dwarf and includes everything in between. In each population a certain mean or average stature is most frequent, small deviations from the mean are common, and large deviations are rare. Variance is a measure of the variability in a given population. It is computed as a sum of squared deviations from the mean, divided by the number of observations. The variance is evidently a compound of genetic and environmental variability; people may be predisposed by their genes to grow tall or short, but the growth may be stimulated or stunted by a variety of environmental factors. Several approaches have been used to measure which portions of the variance are attributable to genetic causes and which to environmental ones. Heritability is a statistic computed as a ratio (or percentage) of the genetic to total observed variance. Heritability "in the broad sense" and "in the narrow sense" may be distinguished, but this is a fairly recondite matter which need not detain us here. The latter heritability is particularly useful for prediction of the gains to be expected from selection practiced by breeders of domestic animals and plants, for example, selection to increase the number of eggs laid by hens or yield of milk from cows. With man such predictions are not yet practicable, because natural selection is hard to measure and artificial selection is a concern for the future.

The heritability of IQ in man is estimated from data of the sort summarized in Table 1–1. Slightly different estimates are obtained from different varieties of IQ tests, from correlations between relatives of various degrees, and between relatives of the same degree reared together and apart. The available estimates have been carefully reviewed by Thomson (1967), and especially by Jensen (1969). Jensen gives an overall estimate of 0.81 (81 percent). This is a high heritability, as the list of heritabilities of various traits in different organisms, compiled in Table 1–2, clearly shows. IQ is about as strongly heritable as human stature. Its heritability is much higher than those of egg production in poultry or of yield in corn. Yet the selection practiced on these latter traits by animal and plant breeders has resulted in substantial improvements. Behavior traits in Drosophila, responses to light and to gravity, have heritabilities an order of magnitude lower than IQ. Genetic conditioning of human characters as little heritable as these would probably be undetectable, and yet artificial selection for some ten to twenty generations induces spectacular changes in the behavior of Drosophila flies.

There has been so much misunderstanding of the significance of the high heritability of IQ that it is imperative to make clear what this heritability does and does not mean. To begin with, it does not mean that the IQ, or scholastic achievement insofar as the latter is a product of IQ, is not subject to modification by upbringing and other environmental means. The cited works of Heber, Skodak, and Skeels have shown this clearly. Even more basic is that the heritability is not an intrinsic property of a trait but of the population in which it occurs. Consideration of limiting cases makes this obvious. Suppose we have a population consisting of genetically identical individuals; all traits would then have zero heritability. A bit less unrealistic is to envisage a population in which all members live in identical environments; all heritabilities would then be equal to unity. Therefore, estimates of heritability are valid only for the populations and for the times when the data on which they are based were collected.

The dependence of heritability on the degree of genetic

TABLE 1-2

Examples of heritability estimates in various animals and plants.

Organism and Trait	Heritability
Spotting in Friesian cattle	0.95
Slaughter weight in cattle	0.85
Stature in man	0.81
IQ in man	0.81
Weight in man	0.78
Cephalic index in man	0.75
Plant height in corn	0.70
Egg weight in poultry	0.60
Weight of fleece in sheep	0.40
Milk production in cattle	0.30
Yield in corn	0.25
Egg production in poultry	0.20
Egg production in Drosophila	0.20
Ear length in corn	0.17
Litter size in mice	0.15
Response to light in Drosophila	0.09
Conception rate in cattle	0.05
Response to gravity in Drosophila	0.04

and environmental uniformity or heterogeneity must be kept in mind in evaluations of the significance of differences observed in IQ and other human traits. With the exception to be mentioned below, the information on which the heritability estimates for IQ are based comes from studies on white and predominantly middle-class populations. Most abundant data pertain to monozygotic and dizygotic twins and siblings reared together, i.e., in the same families. The environments in which children are brought up in the same family are certainly not identical, but they are also not as divergent as they are in families that belong to different socioeconomic classes, castes, or races in different parts of the world. Examples of twins and siblings being reared apart are understandably infrequent, and when they are found they are likely to be placed in not too dissimilar environments.

IQ Differences in Social Classes

If the estimation of the heritability of IQ differences between individual members of the same population is beset with pitfalls, the complexities increase greatly when differences between population means are considered. Since educational and other opportunities are often very unequal for children of different socioeconomic classes, it is not unexpected that their mean IQs and scholastic achievements are also unequal. Burt (1961), Eckland (1967, 1972a, b), and Gottesman (1968a, b) have critically reviewed the pertinent evidence. A short summary of Burt's data on some 40,000 adults and their children in England appears in Table 1–3. Higher professional (I), lower professional (II), clerical (III), skilled (IV), semiskilled (V), and unskilled (VI) occupations are distinguished. The average IQs of the fathers in these categories vary from 139.7 for the higher professionals to 84.6 for unskilled workers. However, the children of the high-scoring fathers are on the average below, and of low-scoring fathers above, the parental means. This is the phenomenon of regression toward the mean well known to geneticists, and already mentioned. Regardless of whether the IQ differences between occupational classes are mainly genetic or mainly environmental, it is clear that the children do not fully inherit either the superior or the inferior performance of their parents.

The situation is analogous with human races. People who

TABLE 1–3

Average IQs of fathers and of their children belonging to socioeconomic classes from I, the highest, to VI, the lowest (after Burt, 1961).

	I	II	III	IV	V	VI
IQs of fathers	139.7	130.6	115.9	108.2	97.8	84.6
IQs of children	120.8	114.7	107.8	104.6	98.9	92.6
Frequency per 1,000	3	31	122	258	325	261

belong to different races, when they live in different countries as well as when they live side by side in the same territory, do not always have equal opportunities for either bodily or mental development. But while members of socioeconomic classes are not as a rule recognizable by physical traits, races usually have externally visible "stigmata" which lead to self-identification and to identification by others. Endless disputes and passionate polemics arise from the finding that the white and black populations in the United States also differ in IQ averages. Assuredly, individual scores are broadly overlapping; many whites score below the black mean, and many blacks are above the white mean. However, the black average is some 15 IQ points below the white average.

Class and race differences in IQ averages may be ascribed to inequalities in educational opportunities and living standards. This explanation is traditionally favored by most social scientists and by political liberals. On the other hand, the differences may be genetic, which is pleasing to racists and reactionaries, but not espoused by any reputable scientist. Finally, both environmental and genetic conditionings may be involved. The bone of contention is then not environment versus heredity, but how much environmental relative to genetic conditioning.

The controversy is growing hotter because of the finding that individual IQ differences have large genetic components. Racists try to obtain maximum propaganda mileage from this fact. Yet the differences between race and class averages need not be genetically conditioned to the same degree as individual differences. Nobody, not even racists, can deny that living conditions and educational opportunities are disparate in races and classes. Jensen (1969), after recognizing explicitly that the heritability of individual differences within a population cannot validly be used as a measure of the heritability of the population means, tries to do just that. In fairness to him, it must be conceded that he presents a most detailed analysis of the environmental factors which could be instrumental in bringing about the divergence of IQ averages in the white and black populations of the United States. His conclusion is that none of the factors, or combinations of factors, give an adequate explanation of this divergence, which accordingly must be largely genetic. I remain unconvinced by his argumentation.

Scarr-Salapatek (1971a, b) may have achieved a breakthrough in heritability studies. The assumption made heretofore in IQ analyses has been that the action of genetic and environmental factors is simply additive. In other words, genetic and environmental agencies that bring about increments and decrements of intelligence (and other mental traits) act independently of one another, and always in the same way. This need not be so at all. Genetic differences may manifest themselves conspicuously in people who develop in favorable and stimulating environments, and remain undisclosed in adverse or suppressive environments. Carriers of genetic endowments who could unfold high IQs under favorable conditions will fare no better than genetically less well endowed people in suppressive environments. If this is so, the heritability of IQ should be lower among disadvantaged socioeconomic groups (classes as well as races) than among the privileged ones. On the other hand, the heritabilities should be uniform if the simple additivity hypothesis is valid. The two hypotheses are empirically testable, and Scarr-Salapatek has made an ingenious and discerning effort to test them.

Among 250,258 children in Philadelphia schools, from kindergarten to the twelfth grade, 3,042 twin pairs were found; 36 percent of the twins were white and 64 percent black. Regrettably, tests could not be made to identify the monozygotic and the dizygotic pairs (presumably because of the expense involved). Obviating this handicap involved resorting to a rather complex statistical operation. Among the twins, 1,028 pairs were of the same sex and 493 were of opposite sexes. These latter were dizygotic. Among the same-sexed twins, there must also have been approximately 493 dizygotics, with the rest monozygotic. This group was, accordingly, a mixture of not individually identifiable mono- and dizygotic twins. The families of the twins were classified according to their socioeconomic status: above median, median, and below median. As expected, the black families were more often disadvantaged:

	Below	Median	Above
Black	634	236	134
White	114	106	340

Aptitude and scholastic achievement test scores of the twins were analyzed statistically. On aptitude tests (where the national mean is 50) the following socioeconomic class and race averages were found:

	Below	Median	Above
Black	27.7	29.7	33.0
White	34.8	43.4	50.9

Differences between the upper- and the lower-class children among the blacks are much smaller (5.3) than among the whites (16.1). What is more important is that the variance of the test scores is greater in the advantaged than in the disadvantaged groups, among both blacks and whites. A greater proportion of the variances found in the relatively privileged than in the underprivileged socioeconomic classes is attributable to genetic causes. This is what the hypothesis of interaction between the genetic and environmental factors (see above) has predicted. The conclusion of Scarr-Salapatek is worth quoting:

> From studies of middle-class white populations, investigators have reached the conclusion that genetic variability accounts for about 75 percent of the total variance in IQ scores of whites. A closer look at children reared under different conditions shows that the percentage of genetic variance and the mean scores are very much a function of the rearing conditions of the population. A first look at the black population suggests that genetic variability is important in advantaged groups, but much less important in the disadvantaged. Since most blacks are socially disadvantaged, the proportion of genetic variance in the aptitude scores of black children is considerably less than that of the

white children, as predicted by model 1 [environmental determination].

Evolutionary Genetics of Caste and Class

The question is sometimes asked: How do you define "man"? Biologically the answer is simple. All human beings are members of a single species, *Homo sapiens.* Though some pathological variants seem to be less than human, they belong to our species. Their genes come from the same gene pool as everybody else's. Inhabitants of the whole world share in the common gene pool of the species. Perhaps no hybrids of Eskimos and Tungus with Hottentots and Aboriginal Australians have ever been produced, but there are unbroken chains of intercrossing of geographically intermediate populations. Assuredly, this does not mean that mankind is a single uniform breeding population, wherein every individual would have equal chance to mate with any individual of the opposite sex anywhere. The population of our species is complexly subdivided into a variety of subordinate Mendelian breeding populations. In each of these, the probability of marriage within is greater than between populations.

Geographic, national, linguistic, religious, economic, and other factors keep the gene pools of the subordinate breeding populations partly, but probably never entirely, separate. Mendelian breeding populations within a species are more often than not overlapping, which does not make them unreal. The population of New York City has WASPs, Jews, Catholics, and blacks; wealthy, moderately well-off, poor, and destitute; educated and ignorant; people of English, Irish, Italian, Greek, and other ethnic groups, partly preserving their cultural backgrounds. Many individuals belong at the same time to two or more of these subpopulations or "isolates."

All these subdivisions are not only social and economic but also biological—a fact which may not be pleasing to social scientists who would like to make their field entirely autonomous from biology. But in man sociological and biological factors are almost always intertwined. The social subdivisions have biological consequences because they influence the choice of marriage partners. Marriages within each subpopulation are more frequent than are intermarriages. The subordinate Mendelian populations may become and may be maintained genetically distinct. The distinctions are almost always quantitative rather than qualitative. That is, gene variants which control some traits, from blood groups to intelligence, may be species-wide in distribution, and yet be found more frequently in some subpopulations than in others. This is not a biological technicality but a fact of cardinal ethical and political importance. Every person must be rated according to his individual qualities, regardless of the subpopulation from which his genes came.

All human societies, even the allegedly "classless" ones (e.g., the Soviet-type communist societies), are stratified into classes. People of a class have life chances in common, as determined by their power to dispose of goods and skills for the sake of income (Lipset, 1968). Classes are not only socioeconomic groups but also breeding populations, to a greater or lesser extent separate from other populations. It is therefore legitimate to ask whether their gene pools are different, and, if so, to what extent (Eckland, 1967; Gottesman, 1968b). The question can be inverted: To what extent, if at all, is the socioeconomic level a function of the genetic constitution?

Members of privileged classes like to believe that everybody belongs to the socioeconomic class for which his genes qualify him. The poor live wretchedly; if this is not through their faults, then it is owing to their genetic inferiority. The opulent and the mighty deserve their affluence because their genes entitle them to it. Such views are an abomination, not to the underprivileged alone but to some prosperous liberals as well. In their protest they often go out on a limb, espousing the indefensibly extremist position that the genetic basis of mankind is uniform everywhere, and need not be considered further. The article of Fried (1968) is a specimen of this genre, written by an anthropologist. The problem can, however, be approached in a less emotionally charged way.

Both as social groups and as breeding populations, socioeconomic classes vary in the degree of their separateness. Caste societies are at one pole and open-class societies at the other. Castes existed, and to some extent continue to exist, not only in India but in many traditional societies, including feudal and capitalist Europe, and to a lesser extent the United States. One belongs to the caste in which one is born, and marries somebody in the same caste. Castes occupy superior or inferior ranks in self-esteem and in the opinion of others. A "society" matron places herself unhesitatingly above the "rabble," which thus becomes another and more numerous caste. The matron is aghast at the thought that her daughter or son may marry someone not of "society," but is a little more indulgent of extramarital affairs and even of illegitimate progeny. The latter are not unimportant genetically. No caste, not even in traditional India, was genetically completely segregated.

Open-class societies permit, or even encourage, social mobility from class to class. People move into, or are coopted by, classes for which they are eligible according to their abilities and achievements. This is the principle of meritocracy. The class is determined not by birth but by personal qualities. The existing societies also form a spectrum in this respect, extending from at least theoretically impervious castes, through more or less rigidly closed, to progressively more meritocratic open classes. Various degrees of closure may be found in the same society. The blacks in the United States can, for the purposes of the present discussion, be treated as a caste rather than a race. Gene exchange between the black and the white castes was, until recently, mainly in one direction, from white to black, and that by way of extramarital unions. The black as well as the white castes contain a variety of socioeconomic classes between which social mobility and gene exchange are regarded acceptable.

We have seen that individual variability within classes and castes is both genetically and environmentally conditioned. This is true of IQ as well as of scholastic aptitude and achievement. The genetic component seems to be more pronounced in relatively more prosperous than among underprivileged socioeconomic groups. It should be kept in mind that IQ is not a unitary trait determined by a single gene; it is a composite of numerous genetic components. The IQ is surely not alone in being genetically conditioned. Less detailed but still substantial evidence suggests that many personality characteristics and special abilities, from mathematics to music, have genetic components in their variability.

It is not an overstatement to say that whenever a variable human trait, down to such far-fetched ones as smoking habits, has been studied genetically, indications of some genetic conditioning have come to light.

It is utterly unlikely that, in meritocratic societies, the incidence of all genetically conditioned behavior traits could remain uniform throughout the whole gamut of socioeconomic classes. A gloss is needed here to ward off a frequent misconception. The statement that genes for such traits as higher or lower IQs, keen eyesight, or musicianship are more common in a class or caste *A* than in *B* does not mean that all *A* persons and no *B* individuals possess these genes. Let me reiterate that, since not all-or-none but only gene frequency differences are involved, an individual's potentialities are determined by his own genetic endowment and not by his class or race origins.

In western societies the trend for several centuries has been from closed caste-like to open meritocratic societies. When western civilization achieved world-wide influence, the trend became universal. Social mobility is increasingly free. In a meritocracy, scholastic ability and achievement are among the paramount determiners of social mobility. Schools and universities are principal ladders for socioeconomic rise. Insofar as achievement is genetically conditioned, social mobility is a genetic as well as socioeconomic process. In Eckland's (1967) words: ". . . talented adults rise to the top of the social hierarchy and the dull fall or remain on the bottom. Therefore, as the system strives to achieve full equality of opportunity, the observed within-class variance among children tends to diminish while the between-class variance tends to increase on the selective traits associated with genetic differences."

Equality of opportunity is an ideal approached in various degrees, but not fully achieved anywhere. This enhances the importance of the argument that, while socioeconomic classes may and probably do differ in statistical averages of some traits, the differences between individual members far exceed the differences between class averages. To quote Eckland again:

> . . . genetic variability guarantees a relatively substantial pool of very bright children from lower-class backgrounds, which is sufficient reason, in both utilitarian and ideological terms, for social policies that emphasize the importance of this overlap. Moreover, when entire groups of children from these backgrounds are systematically deprived of some opportunities for development . . . then the size of this pool is larger than that which otherwise might be estimated on the basis of heritability coefficients alone.

It may chagrin some people to learn that increasing equality of opportunity enhances, not reduces, genetic differences between socioeconomic classes. We shall see, however, that if the equality were made perfect, or nearly so, the classes as we know them now would no longer exist.

Wisdom of Equality and Unwisdom of Inequality

Human equality is an ethical precept, not a biological phenomenon. A society can grant or withhold it from its members. Whether or not ethics are deducible from scientific knowledge need not concern us here, but it is legitimate, and even necessary, to scrutinize the probable consequences of adoption or rejection of a given ethic. There were, and still exist, blatant inequalities in some societies, and various approaches to equality in others. Contrasts of this sort may be found simultaneously in the same society: caste-like segregation and denial of equality to the blacks coexisted until recently in the United States with a relative unconstraint of social mobility among the whites.

One may distinguish equality of opportunity and equality of status. "Whereas equality of status deals with how power, privilege, and prestige are distributed in a society, equality of opportunity deals with the process of status allocation or, in other words, the criteria by which people are selected to fill different roles in society" (Eckland, 1972). Even though equalizations of opportunity and of status usually go hand in hand, they may also diverge. Russia is a prime example of this. The revolution there has enhanced equality of opportunity (without making it anywhere near complete); status inequalities in U.S.S.R. became, if anything, magnified by the totalitarian bureaucratic regime.

A caste system entails inequalities of status as well as of opportunity. It also entails occupational specialization. Each of the numerous castes and subcastes in classical India had a business, trade, or work traditionally reserved to it. The problems of training and allocation of status were thus simplified—everybody knew from childhood what the source of his livelihood would be, and in what kind of occupation or toil he must become skilled. Of course, one belonged to the caste of one's parents, and had to marry a person of the same caste. One could not be promoted or demoted to another caste, no matter what one's achievements, failures, talents, or incapacities. Upper-caste status automatically carried with it respect and privilege; lower castes and outcastes ("untouchables") were subjected to gross indignities.

The system was revoltingly unjust from our modern point of view, yet it had a plausible-sounding rationale. Bose (1951), no partisan of the caste system, wrote: "The careful way in which the tradition of close correspondence between caste and occupation was built up is clear indication of what the leaders of Hindu society had in mind. They believed in the hereditary transmissibility of character, and thought it best to fix a man's occupation, as well as his status in life, by means of the family in which he had been born." The same rationale is offered by racists in the United States and elsewhere for the denial of equality to the black caste. Here is a specimen of Putnam's (1967) specious reasoning: "The relationship as to both employment and welfare which existed for generations between white and Negro families in the South was almost ideal because it was based upon reality. The white family took a cradle-to-grave responsibility for the Negro family and the latter repaid the former in faithful service." This idyllic (to Putnam and his like) relationship assumed that the blacks are genetically specialized for work in no capacity other than as domestic servants. The fatal flaw of all caste systems is that they are built explicitly or implicitly on such assumptions.

The caste system in India was the grandest genetic experiment ever performed on man. The structure of the society endeavored for more than two millennia to induce what we would now call genetic specialization of the caste populations for performance of different kinds of work and functions. Such specialization has not been achieved. The evidence is as yet insufficient to rule out the possibility that some average differences between the caste populations may exist. This much is certain: although modern India has far to go to abolish inequalities of status and opportunity, all castes have produced persons of ample competence to acquire nontraditional education and to engage in nontraditional occupations. Less far-ranging genetic experiments were revolutionary overturns of old elites, which were physically annihilated or forced to emigrate to other countries. Predictions were freely made that such intellectual decapitations would lead to a dearth of talent and competence. The test case of Russia has proved the prediction wrong; talent recruited from the former lower classes, which had no opportunity to manifest itself, has given rise to a new intelligentsia in no way inferior to the old one. An even more drastic test in China awaits completion.

The failures of caste systems are understandable in the light of genetics. Human populations, like those of most sexual and outbreeding species, have enormous stores of all kinds of genetic variability. Even with artificial selection directed specifically to this end, it is practically impossible to obtain a population completely homozygous for all its genes. Close inbreeding, such as brother-sister mating for many generations, is more likely to result in genetic uniformity, but it is hard to control just what genetic endowment will become fixed. Anyway, neither strong artificial selection nor close inbreeding have ever been systematically practiced in the human species, and there is no immediate prospect of their adoption. Ours, happily, is not Huxley's *Brave New World*. All human populations, even the relatively inbred ones, conserve ample supplies of genetic variance.

The gene pool of every caste generates genetic endowments whose carriers could perform competently, and even achieve excellence, in occupations reserved by custom for other castes. For the sake of argument, assume that a caste population was at some point in time genetically better adapted than other castes for some task. There existed castes of priests, scholars, warriors, tradesmen, and so on. Could the differential adaptedness be maintained for many generations, except by systematic training of the young in the traditions of their families and ancestors? Genetically conditioned adaptedness will gradually be dissipated for at least two reasons. First, inept progeny will be pressed to follow their parents' careers despite the genetic incapacity. Second, whatever natural selection may have operated in the formation of the caste gene pool will probably be modified, abandoned, and perhaps even reversed.

Wastage of talent is, in fact, a fatal vice of all caste and rigid class systems. When social mobility is interdicted or seriously impeded, individuals qualified by their abilities to enter a given occupation are not admitted, and unqualified ones are retained. As the class structure becomes more open, impediments to social mobility decrease, and the principle of meritocracy becomes dominant. One's status and role in a society are acquired and not inherited from the parents. What may seem surprising at first is that when social inheritance of role and status becomes less influential, the importance of biological inheritance increases. This is a consequence of the genetic conditioning of those human characteristics which determine social mobility in open-class societies.

In a meritocracy, one's socioeconomic situation is a function of one's ability and achievement, rather than, or at least in addition to, inherited wealth or lack thereof. Educational institutions become channels of social mobility. Scholastic success is a function of aptitude and of willingness to exercise it, and aptitude is in part genetically conditioned. Since education and socioeconomic position are highly correlated, the status and material rewards are also indirectly genetically conditioned. Herrnstein (1971) puts this bluntly: "In addition to everything else, a high IQ pays in money." He offers the following syllogism as a clincher: "If differences in mental abilities are inherited, and if success requires those abilities, and if earnings and prestige depend on success, then social standing (which reflects earnings and prestige) will be based to some extent on inherited differences among people."

Have we arrived, in a roundabout way, at the conclusion so precious to race and class bigots, that the rich and the poor, the mighty and the humble, the elites and the reprobates, are where there genes have placed them? This is a misleading oversimplification. One must, first of all, distinguish two parts of the problem: the social status achieved by an adult person or a group of persons, and the choice of careers and ascription of status in their offspring. Excepting only the most rigid caste societies, the adult members of a society have always passed through some kind of social selective process. Their occupations, prestige, and positions on the social ladder reflect at least to some extent their abilities, conditioned by their environmental opportunities or by their genes—it does not matter which for the present argument. The question that now logically presents itself is this: To what extent does the social position of the offspring reflect the abilities of the parental or of the filial generation? Customs in many societies encourage, and often compel, children to follow the footsteps of their parents. Parental emotional impulses make the parents exert efforts to ease the ways of access for their children toward occupations and careers considered desirable or worthy. To the extent that these customs and impulses hold sway, the selective process is frustrated. This may happen even with apparently quite fair competitions, as in competitive tests and examinations for admission to certain schools. To what extent is the success or failure due to the intrinsic abilities of the examinees, or to the advantages and handicaps of their home environments and upbringing? This may not matter greatly to the selectors, if the purpose of the selection process is to obtain a group of individuals best able to profit from certain training. This is not so for the selectees and for the society as a whole, since many highly capable individuals are kept from admission to training and careers in which they could excel.

At this point one should be reminded of a basic fact of genetics which is all too often ignored. An individual's physical and mental constitutions are emergent products, not a mere sum of independent effects of his genes. Genes interact with each other, as well as with the environment. A gene B may enhance some desirable quality in combination with another gene A_1, but may have no effect or unfavorable effects with a gene A_2. Such nonadditive (epistatic) effects may be important determiners of intelligence, personality, special abilities, and other mental traits. For this reason, as well as because of the regression toward the mean, it is not at all rare that talented parents produce some mediocre offspring, and vice versa.

Assume, for the sake of argument, that at a certain time in history four castes or rigid socioeconomic classes are formed, composed initially of persons of demonstrated intellectual prowess (scholars), refined aesthetic discrimination (artists), physical valor or bravery (warriors), and luxury-loving social parasites. Assume further that these qualities were due to training and circumstances as well as to genetic conditioning. Shall we then have these four castes perpetuating themselves from generation to generation, with their respective characteristics unchanged? This is doubtful, for several reasons. It is highly unlikely that everybody in the original (founding) population of every caste carried the same genes, and even less likely that they were homozygous for these genes. The same degree of achievement in a given field can be due to diverse genetic endowments. Genetic (Mendelian) segregation will, therefore, generate from generation to generation an increasingly greater variety of genetic endowments, many of which will not equal or even approach those of the founders. Add to this the unlikelihood of absolute endogamy in any human population. A trickle, or even a stream, of foreign genes will gradually but inevitably dilute the original gene pool of the founders. For these reasons, all kinds of talent, excellence, and even genius arise throughout the social edifice. They appear on all socioeconomic levels, even though they may be more likely in a statistical sense to be found in some than in other places. But a human being is a unique and nonrecurrent person, not a statistic; he deserves to be judged on his own merits, not according to the merits or demerits of his relatives.

Most discussions of genetic aspects of social stratification tacitly assume the value systems and political orders of modern quasidemocratic and meritocratic societies. It is a moot point whether the same kind of intelligence that leads to social preferment in these societies would do so everywhere. Modern China seems to be bent, not on searching for, but on abolition of elites, and on a radical leveling down of all socioeconomic disparities (Singer and Galston, 1972). If this is so, then either submissiveness and docility, or utter selflessness and ant-like dedication to the interests of the society as a whole, are now requisite for survival in something like a quarter of all mankind. It is wise to suspend judgment on whether the Chinese system will work out better or worse than ours.

A limited number of vacancies on the upper and intermediate levels of the social pyramid are available to much greater numbers of claimants in open-class societies, of the capitalist as well as of the Soviet communist kinds. A cut-throat competition takes place for the occupation of these vacancies. One wonders how often the winners in this competition are really best as human beings. Caste and rigid-class societies unforgivably wasted genetic talent and ability when these appeared among the lower orders of society. But it must be admitted that such societies did lessen the obnoxious aspects of competition. There is something to be said for the old-fashioned aristocrat who could afford to be gracious and magnanimous because he knew that his status was secure without contest.

Another tacit assumption should be brought into the open. Evaluation of scholastic ability and achievement usually takes for granted the educational system established in a given country. Those who succeed are rated superior and those who fail inferior. But is it possible that part of the blame should be charged to the educational system rather than to those who fail to pass the tests satisfactorily? It is well known, particularly to animal and plant breeders, that carriers of different genetic constitutions may respond most favorably to different environments. This is probably even more true of human genetic endowments. Ideally, every child should receive the environment most conducive to the development of his own particular abilities. Heber (1968) shows that spectacular improvements in manifested ability can be secured at the cost of concentrated effort. To what extent the ideal can be translated into practice is another matter. Some abilities may be judged more important than others in a given society. It must nevertheless be recognized that when everybody is put through the same educational machine, the abilities of many people will be grievously misjudged.

Genetic Sequelae of Perfect Equality

A decade ago (Dobzhansky, 1962) I attempted to envisage the genetic processes in a society with complete equality of opportunity for all its members. I was aware that this borders on utopia, but in recent years "futurology" has become something of a fashion among many social as well as natural scientists. The matter deserves a more detailed consideration.

A model of full equality of opportunity and of social mobility, favored by some sociologists, has been justly criticized by Eckland (1967). The model implicitly assumes that human ability is only environmentally determined and is randomly distributed in all socioeconomic strata. Full equality would then mean that identical proportions of children born to parents of different strata must enter any given occupation and achieve any given income level. Eckland points out that with this model "we would have to accept the unrealistic idea that, biologically, there is no more resemblance between a child and his parents than between a child and a total stranger."

In point of fact, people vary in their capacities to take advantage of opportunities that they meet, and these capacities are in part genetically conditioned. It appears undeniable that, in western postindustrial, quasi-democratic and meritocratic societies, IQ scores are fairly accurate predictors not only of scholastic but also of occupational achievement and, at a further remove, of income level and social status. Free mobility and perfect equality would then mean a perfect correspondence among intelligence, occupation, and status in a given society. Scarr-Salapatek (1971a) describes the resulting paradox as follows: "The greater the environmental equality, the greater the hereditary differences between levels in the social structure. The thesis of egalitarianism surely leads to its antithesis in a way that Karl Marx never anticipated." Liberals, progressives, egalitarians strove for abolition of class privilege and for equality of opportunity. The outcome, in capitalist as well as in socialist societies, would seem to be formation of genetically fixed classes. According to Eckland (1971), "In a completely open society under full equality of opportunity, a child's future position may be just as accurately predicted from the status of his biological parents as in a caste society. The basic difference between the two being that in a completely open system the causal links between generations would involve character specific or polygenic traits like intelligence, whereas in a caste system the links are consanguineous or cultural."

This sociogenetic model is an oversimplification. There is no denying that high-grade ability (whether genetically or environmentally conditioned) tends, in a meritocracy, to become concentrated in those positions which bring greater material rewards and prestige. It is, however, essential to keep in mind that human abilities are not only quantitatively but also qualitatively diversified. People achieve excellence in artistic, intellectual, administrative, political, athletic, commercial, and other pursuits and careers. It would be fatuous to rank these different pursuits in any order of increasing or decreasing merit. An individual engrossed in and dedicated to art may be uninterested in athletics, and vice versa. Yet equal material rewards and fame can be achieved in any one of these and other lines of endeavor. This is not contradicted by a statistical predictability of occupational and economic success from measurements of scholastic ability and achievement. It is not self-evident that a moderately low IQ (of course, not down to gross mental retardation levels) is a severe impediment for excellence in, say, baseball or boxing careers.

The concentration of human behavior geneticists on IQ studies is justified because the IQ, whatever its other defects, is measurable. But it is apt to obscure the fact that other, and perhaps equally heritable, characteristics and abilities play significant roles in choice of and success in different occupations. How about persistence, willingness to work, originality, creativity, leadership, ability to get along well with others, and plain human decency? Information available on the genetic conditioning of these abilities is fragmentary and inconclusive, and yet what information there is suggests that they may perhaps be grounded in the genetic endowment. Equal socioeconomic levels can be reached, in a meritocracy, by means of proficiency or excellence in quite diverse fields, provided that they are recognized in the society as useful. A mathematical genius may achieve fame, high status, and reasonably high income where there are universities and academies, but not in a tribe of hunters and gatherers. In some of the latter, the ability to go into trance or hypnotic state is valued highly (whether or not the latter ability is genetically conditioned is a different problem). Status and income are not absolutely correlated. Though most people like to have both a high status and a high income, some are more strongly attracted by the former and others by the latter. Examples are clergymen (relatively high status) and morticians (relatively high income).

Equality of opportunity has, then, two aspects. First, everybody is entitled to have access to the whole range of status and economic levels, regardless of the status or level of his parents and relatives. "Access" means that anyone may choose to strive and compete, or not to compete, for any position in the society; obviously it does not mean that the desired position will always be achieved. This depends on the adequacy of one's qualifications for that position. The wrong of caste and rigid class societies is that people are arbitrarily barred from access to a great many positions.

The second, and less evident, condition of equality of opportunity involves recognition that different people, carrying different genetic endowments, require different environments for their self-realization. A potential musical virtuoso is denied opportunity to develop his powers if he is prevented from entering a conservatory of music and is obliged instead to undergo the same training as, for example, future engineers. Ideal equality would entail provision of a set of diverse educational paths which people will choose, or be recommended to take, in accord with their tastes and abilities. In practice, this raises a host of thorny sociological and ethical problems. Is it inevitable that some children and youths will be selected as fit prospects for occupations or positions which are regarded for various reasons as more desirable, and others will be designated as lacking any particular talents? This can easily become a disguised form of social privilege.

Is there an escape from this impasse? It seems that it can only be found in some variant form of the socialist principle: "From each according to his abilities, to each according to his needs." This is not necessarily impossible to achieve in nonsocialist societies as well. Gross inequalities in material rewards may be eschewed. After all, some redistribution of wealth, making it more equal and equitable, has been going on in most technologically advanced countries for at least half a century (provoking cries of "creeping socialism" in some quarters). Perhaps equally important is avoidance of gross inequalities of status. This is at least in part a matter of ethics; an office or plant chief need not treat the janitors and charwomen with snobbish condescension.

And yet it is desirable and even indispensable for a society that those who possess rare or unusual abilities in some fields be induced to strive to achieve excellence in those fields. This usually means a more prolonged and arduous training than is requisite for more common and simpler occupations. Is it only desire of greater economic and status rewards that induces people to devote themselves to pursuit of outstanding achievement? With many people this is so, but with others achievement is self-rewarding. A musician, a poet, a craftsman, an athlete, and even a scientist and a politician derive a high degree of satisfaction and happiness from their works when they feel that their products are turning out well. It is not unheard of for people to turn down offers of greater economic rewards for the sake of being left free to pursue their favorite endeavors. It is not inconceivable that a day will be reached when the greatest monetary rewards will go to those engaged in socially indispensable but disagreeable work, such as garbage disposal, while those in occupations that tend to be self-rewarding may have to rest content with smaller emoluments.

Freedom of choice of training and occupation may entail wastage of effort and society's resources. Somebody striving to be a poet may turn out to be at most a poetaster, and an ambition to become a scientist may end in one's becoming a humdrum technician. Dashed hopes are painful to the person concerned, but denial of the right even to aspire for admission to some opportunities in a rigid class society is far more devastating. Any organization of society set up by fallible humans will fall short of perfection, but I firmly believe that one should work for as near an approach to full equality of opportunity and of status as can be secured. The two aspects of equality discussed above are indispensable: the ability freely to choose the goal of one's life and the direction of one's efforts, and the provision of a variety of environments, and of kinds of upbringing and training, suitable for diverse endowments of different persons.

Socioeconomic Classes or Aptitude Aggregations?

It cannot be overstressed that it is not the purpose of human equality to make everybody alike. Quite the opposite—it is a practical recognition that every individual is different from every other, and that every person is entitled to follow the path of his own choosing (provided he causes no injury to others).

Human genetic diversity is not a misfortune or a defect of human nature. It is a treasure with which the evolutionary process has endowed the human species. The companion treasure is the genetically conditioned educability, trainability, or malleability of human beings. Any human society, from the most primitive to the most complex (the latter more than the former), needs a diversity of men adapted and trained for a diversity of functions. Caste societies attempted, and failed, to achieve the requisite diversity by exploiting the real or imaginary genetic differences among men. Whether or not the diversity could be achieved in a meritocratic society by differential training if all men were genetically as similar as monozygotic twins is questionable. In reality, the diversity is obtained by a combination of genetic and environmental conditioning. The functionalist paradigm widely accepted in modern sociology assumes that "a key requisite for an operating social system is a relatively stable system of social rankings. . . . Given this assuption, an ongoing system of stratification requires a general set of ideological justifications. There must be various mechanisms which explain, justify, and propagate the system of inequality, and which cause men to accept as legitimate the fact of their own inequality. From an ideal-typical point of view, a system of stratification that is stable would set for various groups within societies goals that could be achieved by all within each group" (Lipset, 1968).

Equality is necessary if a society wishes to maximize the benefits of genetic diversity among its members. With anything approaching full equality, every trade, craft, occupation, and profession will concentrate within itself those who are genetically most fit for these roles. Will these aggregations of genetic aptitudes amount to restoration of classes or even castes? The aptitude aggregations may develop into novel social phenomena, barely foreshadowed at present.

Critics of the functionalist paradigm have pointed out "that systems of stratification persist and take the varying forms they do because the privileged strata have more power and are able to impose their group interests on the society. . . . The value systems related to stratification therefore reflect the functional needs of the dominant strata, not those of the social system as such" (Lipset, 1968). The aptitude aggregations will differ from the old classes before all else by their fluidity. An aggregation will be gaining new members who are not descendants of the old members, probably in every generation. The gains will be more or less offset by losses of some of the progeny of the old members, who will pass to other aggregations. The gains and losses may be due in part to some occupations becoming more or less attractive, or more or less socially important, so that more or fewer people are willing to be trained for them. Other gains and losses are genetically conditioned, and hence genetically significant. They result from segregation of Mendelian genes, and should not be frustrated by the "natural" and emotionally understandable impulses of parents to make their children inherit their occupations and status, or to propel them into what is regarded as more privileged occupations and status.

It is unlikely that the aptitude aggregation of, for example, musicians could have every member homozygous for the same gene for music, even if such a gene existed. The genetic basis of musical talent is probably a constellation of several genes, and possibly different genes in different persons. It is even less likely that every spouse of every musician is homozygous for the same gene or genes. Some of the progeny in families of musicians will, then, lack conspicuous musical talents, and will pass to other professional aggregations. Conversely, some talented musicians are born in families of these other aggregations, and will be absorbed in the aggregation of musicians. This is analogous to the present interclass social mobility, but more closely tied to genetic processes in human populations. Moreover, the mobility should not be conceived as unidirectional but as multidirectional. Instead of moving up or down a single socioeconomic scale, the exchange of persons and of genes occurs between more or less numerous functional aggregations, some of which are economically equivalent.

Children of musicians, or athletes, or intellectuals grow up in environments in which musicianship, or athletics, or intellectual pursuits are likely to be appreciated and encouraged. Although not every offspring in such families inherits the genes that condition the respective talents or inclinations, the probability of talented individuals being born in such families is greater than in other families. Furthermore, the genetic consequences of assortative matings should not be underestimated. The genes for a certain kind of aptitude are found scattered in all social strata and in all professional aggregations. Nevertheless, the marriage of individuals who carry genes for similar aptitudes will occur more often than would be expected by chance alone. Assortative matings need not be due to conscious choice, but may be rather a matter of propinquity. Statistically speaking, families engaged in similar occupations are more likely to be acquainted than those in different occupations. My wife and I were once surprised to find that more than 90 percent of persons on the list of our acquaintances were either themselves engaged, or were married to persons engaged, in academic professions. Schools, colleges, and universities function as assortative marriage brokers simply by bringing together young people of similar interests and roughly similar abilities (Eckland, 1970).

The genetic consequences of positive assortative mating have not been adequately analyzed genetically. Considered formally, assortative mating promotes increased homozygosis for the genes that determine the charactistics involved in the choice of mates. The most interesting and significant aspect from the standpoint of human societies is the increase in variance in the populations in which assortative matings frequently occur. Most human aptitudes form graded continua, and are conditioned by several genes reinforcing each other's action. Some people are tone-deaf and find music a nuisance, others are mediocre or fairly good, still others are excellent musicians, and there are also geniuses, like Bach or Beethoven. With random mating, and with genes conditioning a given ability scattered in the population, the likelihood of many of these genes coming together by chance is relatively small. It is increased when the carriers of these genes are more likely to mate with each other than with noncarriers. The aptitude aggregations formed under equality of opportunity would lead inevitably to positive assortative mating. This will not necessarily yield a bumper crop of geniuses (too little is known about the genetic bases of human abilities for such predictions), but the probability of such events is enhanced.

Conclusions

It is hardly surprising that equality is not welcomed by everybody. Some biologists have managed to concoct horrendous tales of its supposedly dysgenic consequences. Equality has, allegedly, drained the lower classes of genetic talents that were occasionally found there in the good old days of class societies which discouraged social mobility. What remains at the bottom of the socioeconomic ladder are worthless dregs. This fantasy is easily dispelled by considering how recent are tentative attempts at equality of opportunity, even in socially advanced societies. However, there is a real sociogenetic problem which should not be lost sight of because we reject the fantasy. We have seen that, in a society approaching full equality of opportunity, there will be formed diverse aggregations of people, concentrating different genetic aptitudes. Is it realistic to envisage a society consisting entirely of such elite aggregations? Or will there be left over a large aggregation devoid of any particular aptitudes, except for occasional birth of some elite gene constellations?

Given the present state of ignorance of human behavior genetics, it would be folly to propound dogmatic answers to the above questions. I agree with Scarr-Salapatek (1971a) that differences between humans "can simply be accepted as differences and not as deficits. If there are alternate ways of being successful within the society, then differences can be valued variations on the human theme regardless of their environmental or genetic origins." People need not be branded elites and commonality. Increasing equality of status and economic equality must complement equality of opportunity. Manual labor is not intrinsically inferior to intellectual labor, even though more people may be adept at the former than at the latter. Efforts to uncover rare abilities need not detract from appreciation of more common ones. All this is admittedly hard to accept for those who were brought up in class societies or in societies that encourage unrestrained competition for status. I feel, however, that this is ethically desirable, and, moreover, that history is moving ineluctably in this direction.

Finally, again one must stress that the diversity we observe is a joint product of genetic and environmental differences. The observed diversity is, in principle, controllable by genetic as well as by environmental means. The more that becomes known about the causes that underlie the diversity, the greater the possibilities of control. This is the ultimate purpose and justification of scientific research in biology, psychology, and sociology. A considerable part of mankind, from city slums of the richest country in the world to the inhabitants of the have-not countries, are at present deprived not only of optimal but of simply tolerable conditions for physical and mental development. This part of mankind must be helped to secure such conditions. It is hypocrisy to say that their deprivations come from their inferior genes, and must be corrected by eugenic elimination of these genes. Eugenics will eventually come into its own. But, as Osborn (1968) has pointed out, eugenic amelioration can only be successful given antecedent environmental and sociological improvements.

2

EVOLUTIONARY GENETICS OF RACE

"It is not my intention here to describe the several so-called races of men; but to inquire what is the value of the differences between them under a classificatory point of view, and how they have originated." This is Darwin's sentence opening the chapter "On the Races of Man" in *The Descent of Man* (1871). A century later, it remains appropriate to open a discussion of the races of man in the light of genetics with the same sentence. Despite the enormous growth of information concerning racial variation in man

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as well as in other organisms, the problems which occupied Darwin are still at issue. In a sense, the incertitudes have increased. It is the contention of a small but vociferous group of students that mankind is not differentiated into races. Even if this contention were justified, which I believe is not the case, our discussion would not lose its point. If mankind has no races, it is surely not homogeneous or uniform. The diversity would still have to be described, studied, and explained.

Genetic diversity among humans is a matter of far more than theoretical or academic interest. It has great many sociopolitical implications. Race diversity is a form of genetic diversity that is often involved in sociopolitical debates. All too frequently, strong biases and partisan feelings are elicited by a mere mention of "race problems." The biological phenomenon of races within the human species appears to be more complex than are races in sexually reproducing and outbreeding species of animals and plants. This is because human races are subject to cultural as well as to biological influences. The greatest trouble is that the study of races in man is beclouded by partisan bigotries. An "ivory tower" scientist prefers to stay away from problems which arouse such emotional biases. And yet, the human importance of the many issues relevant to race is too great to allow the problem to be held in abeyance, or to be given a free run by the bigots. Clarification of biological and other aspects of the race phenomenon is greatly needed.

Individual and Group Diversity

Immanuel Kant, who was a naturalist before he became the prince of philosophers, wrote in 1775 the following remarkably perceptive lines: "Negroes and whites are not different species of humans (they belong presumably to one stock), but they are different races, for each perpetuates itself in every area, and they generate between them children that are necessarily hybrid, or blending (mulattoes). On the other hand blonds and brunets are not different races of whites, for a blond man can also get from a brunette woman, altogether blond children, even though each of these deviations maintains itself throughout protracted generations under any and all transplantations."

Kant understood the distinction between individual (*intra*-populational) and group (*inter*populational) variabilities more clearly than do some modern authors. In our modern terminology, the situation can be described as follows. Excepting only monozygotic twins and other multiple births, any two individuals differ in several, probably many, genes. Parents and children, siblings, more remote relatives, and people not known to be related, differ, on the average, in more and more genes. A person's genotype is unique, unprecedented, and nonrecurrent. As shown in the first chapter of this book, the proximate source of individual genetic variability is Mendelian segregation in sexually reproducing and outbreeding populations. An individual is heterozygous for many (probably thousands or tens of thousands) of his genes. No two sex cells that he produces are likely to contain the same identical sets of genes; the sex cells of his mate are equally diversified; the zygotes (children) which they bring forth will be, on the average, heterozygous for and different in as many genes as their parents were.

With group variability, the units of study are no longer individuals, but biologically and genetically connected arrays of individuals—populations. It rarely happens that every individual of a population *A* differs in the same way from every individual of the population *B*, and the arrays *A* and *B* consist of genetically identical individuals. Such a situation does occur in organisms, chiefly but not exclusively some groups of plants and microorganisms, in which the prevalent or obligatory methods of reproduction are asexual fission, budding, diploid parthenogenesis, or self-pollination. Thousands or even millions of individuals among such organisms belong to the same clone (result of asexual reproduction) or pure line (self-pollination), and may have the same genotypes. These are, indeed, "pure races." The inhabitants of a territory can be described by listing which pure races occur there, and specifying their relative frequencies. To cite a single example, Allard and Kannenberg (1968) found in central California at least eight pure lines of the self-pollinating grass *Festuca microstachys*; the relative frequencies of these lines differ from locality to locality, apparently depending on which lines are best adapted to the environments of a particular locality.

To describe human populations in terms of the proportions of different "pure races" or "types" has been a dream of some physical anthropologists, and this dream dies hard (see Dobzhansky, 1970). But it is a pipe dream, because mankind is, and always was, a sexually reproducing and outbreeding species. Excepting monozygotic multiple births, it has and can have no clones, no pure lines, and no pure races. It consists of genetically unique individuals. False leads to the dreamland of "pure races" have nevertheless abounded. It would be so nice to be able to tell to what pure race every individual belongs!

Human populations are polymorphic for eye and hair colors, blood groups, and many other traits. Could one declare blue-eyed persons to constitute one race and brown-eyed another? Or may one race include the possessors of blood group O, another of A, and the third of B? This would be ludicrous; parents and children, as well as siblings, would often find themselves belonging to different races. Equally meaningless races of criminals, aristocrats, or people suffering from tuberculosis or other diseases have been discussed and written about. The fallacy is that the groups of people concerned are not populations in the biological sense, but collections of individuals arbitrarily selected according to single traits. After all, criminals are born mostly to parents who are not criminals, and some of their offspring are not criminals either. There probably is a genetic predisposition to tuberculosis, but people suffering from this disease are not a breeding community separate from healthy ones. Except in a caste system, no aristocracy or ruling elite is a Mendelian population separate from the plebeians.

The notions of pure races and of Platonic types or ideas are lurking in the background of various taxonomies of constitutional types. Kretschmer's pyknic, athletic, and asthenic body builds and associated psychological types are admittedly rare in their extreme or pure forms. Nevertheless, they can be perceived among the manifold products of the general miscegenation in which mankind has been engaged for centuries and millennia. Sheldon's 88 somatotypes are combinations of graded series of three supposedly independent variables—endomorphy, mesomorphy, and ectomorphy. The genetics of these variables is obscure. If there existed series of multiple alleles in each of the three genes, for endomorphy, mesomorphy, and ectomorphy, the 88 somatotypes could be interpreted as an elaborate instance of intrapopulational polymorphism. This remains to be demonstrated.

For more than half of a century, the Polish school of anthropology consistently adhered to strictly typological assumptions (see the reviews by Czekanowski, 1962, the venerable dean of this school, and also Wiercinski, 1962, and Bielicki, 1962). Populations are described in terms of the incidence in them of racial "types," which are "distinguished by diagnosing the racial affinities of individuals independently of their ethnic origins." European populations are composed of Nordic, Mediterranean, Armenoid, and Lapponoid races or racial types. The frequencies of these types in each population are given with a precision to one-tenth of 1 percent, as though men belonged to one or another clone or pure line, like *Festuca microstachys* grasses (see above). Mediterranean individuals in the Polish, Swiss, and Italian populations are assumed to be more alike than any of these is to his Nordic or Armenoid neighbors or brothers. Michalski and Wiercinski can identify as many as 16 "racial elements" of which mankind is a composite. Each of these races, or types, or elements is recognized by a constellation of chiefly morphological traits, such as stature, eye and hair color, hair form, cephalic, orbital, and facial and nasal indices. A set of mathematical techniques has been devised to identify to which racial type every individual belongs. Can this really be accomplished? As with biological mathematics generally, the results of even the most precise and elaborate calculations do no more than give numerical expressions of the biological assumptions put at the base of the mathematical model. These assumptions in the present case, insofar as they have been stated at all, are untenable. The crucial assumption is that the trait constellations which supposedly identify the Nordic, Armenoid, Lapponoid, and so on, racial types are inherited as alleles of a single gene, somewhat like those giving O, A, and B blood groups. This is in flat contradiction to all that is known about the genetics of these traits. Wiercinski (1962) gives an example of a family in which the father is diagnosed as Alpine, the mother as Nordic, and their two children as Lapponoid and Nordic. This stretches one's credulity to the breaking point.

Mendelian Populations

A person has two parents, four grandparents, eight great-grandparents, and so on. Continued for some 33 generations, the number of ancestors turns out greater than the total world population. Of course, this is impossible. Notwithstanding the universality of incest taboos, all our ancestors were more or less distant relatives. Though this cannot be documented, all humans are relatives. If one could construct a complete pedigree of all mankind, it would be a complex network on which every individual is multiply related to every other. Mankind is a complex Mendelian population, a reproductive community all members of which are connected by ties of mating and parentage. A Mendelian population has a common gene pool. The genes of every individual are derived from, and unless he dies childless some of them return to, this pool.

In theory, mankind could be described by listing its gene loci, and indicating the frequencies in the gene pool of the different alleles at each locus. Such a description, even if it were possible in practice, would not be entirely satisfactory.

Mankind is not a panmictic population, in which every individual would have an equal probability of mating with every individual of the opposite sex and of the appropriate age. The chance is greater that a boy born in Canada will marry a Canadian girl rather than a girl from China or Uganda. In common with many sexually reproducing animal and plant species, mankind is differentiated geographically into subordinate Mendelian populations; intermarriage within these subordinate populations is more frequent than between them. There are also specifically human agencies which cause further discontinuities in the intermarriage patterns, such as economic, social class, linguistic, religious, and other subdivisions.

Mankind, the biological species, is the inclusive Mendelian population. Within it is a hierarchy of subordinate Mendelian populations, geographically or socially partially isolated from each other. Only the smallest subdivisions, inhabitants of some villages, groups of equal social status in small towns, may be regarded as approximately panmictic. Races are subordinate Mendelian populations within a species. They are not Platonic or statistical types, not collections of genetically identical individuals, and not subdivisions of primordial mankind submerged by lengthy miscegenation. They are Mendelian populations which differ in the incidence of some genes in their gene pools.

Delimitation of the Mendelian population of the human species as a whole presents no difficulty. At our time level there is no gene exchange between the gene pool of the human species and that of even its closest biological relatives, pongids or anthropoid apes. It is sometimes asked how one defines a human being. Biologically, the answer is simple: any individual is human whose genes are derived from the gene pool of the human species. By contrast, delimitation of the Mendelian populations which are called races is always to some extent vague, because their gene pools are not wholly disjunct. This is a restatement in modern terms of Darwin's conclusion that "The most weighty of all arguments against treating the races of man as distinct species, is that they graduate into each other, independently in many cases, as far as we can judge, of their having intercrossed."

The subordinate, intraspecific, Mendelian populations, in man as well as in other sexual organisms, are as a rule not fully discrete. Because of gene exchange, they merge into each other. Very often one cannot tell where one ends and the other begins. Even for the major human races (yellow, white, black, and red), frankly intermediate populations occur which defy all attempts of placing them into one or the other of these pigeonholes (for example, are the Turkic-speaking tribes of Central Asia yellow or white?). With the finer geographic, linguistic, or economic subdivisions, the boundaries of the subordinate Mendelian populations are even more blurred, because intermarriage and gene exchange between them occurs increasingly often.

The lack of sharp boundaries between subordinate Mendelian populations in man is disconcerting to some orderly minds. How can one make something so ill-defined the basic unit of biological and anthropological study? Two observations can be made in this connection. First, the complexities of the order of nature should not be evaded. Second, the only way to simplify nature is to study it as it is, not as we would have liked it to be.

Gene Exchange

Biologically basic, and until the advent of culture the only factor maintaining (though not in itself producing) the genetic differentiation of intraspecific Mendelian populations, was isolation by distance.* This phenomenon is very complex, and still far from adequately understood. Probably the most penetrating analyses thus far are those of Wright (a detailed summary and review of the literature in Wright, 1969). Three models have been suggested. Mathematically the most tractable is the "island" model; the other two are isolation by distance over a uniform inhabited area, and the "stepping-stone" model. The island model assumes that the species consists of discrete colonies within which panmixia prevails, but which receive the proportion, *m*, of immigrants drawn at random from the rest of the species. The isolation of the islands may vary in space and in time, the value of *m* ranging from zero (complete isolation) to one (no isolation). If the immigrants come (as they usually do) from the neighboring colonies, rather than from the species

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* Isolation by distance, or geographical isolation, should not be confused with reproductive isolating mechanisms, which act as barriers against gene exchange between incipient or full species. Reproductive isolation is by definition genetic. For example, ethological isolation, lack of sexual attraction between females of one and males of another species, is conditioned by some of the gene differences between these species. So is hybrid inviability and hybrid sterility. By contrast, geographically isolated populations, such as those inhabiting different islands, may, in principle, be genetically identical. Even if they are not genetically identical, the differences between them need not be responsible for their geographical separation. Only ecological isolation, genetically conditioned preference for different habitats, is in a sense intermediate between geographic and reproductive isolation.

at large, we have the stepping-stone model. This merges into the situation in which the distribution area of the species is inhabited continuously and uniformly, but the mobility of individuals is limited, so that the parents come from a more or less small fraction of the total area.

Situations conforming to all three models, as well as intermediate states, are found in man. Cavalli-Sforza (1959; and Cavalli-Sforza and Bodmer, 1970) studied the "matrimonial migration" among towns and villages of the Parma diocese in northern Italy, and Harrison (1967) studied villages in Oxfordshire in England. The bride and groom may be inhabitants of the same village, or the mates may be from different villages. Both authors found that the probability of marriage is a negative exponential function of the distance between the villages in which the potential mates reside. It is also a function of the numbers of inhabitants in the villages; the greater the population of a village, the more potential mates it contains. Harrison's data for the marriage distances in the population of the parish of Charlton, according to the statistics of 1861, show that places within one mile from Charlton contributed some 55 mates per 1,000 inhabitants, while places four or more miles away contributed five mates or fewer.

An important factor in matrimonial migration, and consequently in the gene flow between Mendelian populations, is not only physical distance but also facility of travel. Cavalli-Sforza found the following distribution of marriage distances among the inhabitants of level and mountainous parts of the Parma diocese in Italy (Table 2–1).

The mobility among the inhabitants of the plain is greater, except perhaps at distances of more than 42 units, than

TABLE 2–1

Matrimonial distances in percentages among the inhabitants of the plain (P) *and mountainous* (M) *parts of the Parma diocese* (*after Cavalli-Sforza, 1959*).

Distance	P	M
0– 2.5	51.3	64.2
2.5– 6.5	9.9	9.9
6.5–12.5	15.2	6.6
12.5–20.5	9.9	6.3
20.5–30.5	6.0	3.9
30.5–42.5	3.7	1.8
> 42.5	3.7	6.7

NOTE: A unit distance is 0.625 km.

among the mountaineers. Cavalli-Sforza and Bodmer (1970) have correlated this greater mobility, and also the greater population density on the plain than in the mountains, with genetic differentiation of the village populations. Common genetic markers, OAB, MN, and Rh blood types, have been recorded in the populations. No significant differences between the villages of the plain were found, while an appreciable heterogeneity was brought to light among the mountain villages. The highest heterogeneity was observed in the parishes ("comune") with lowest population densities.

Neel (1969) and his collaborators carried out gene frequency studies of 25 different gene loci in 39 villages of the Yanomama tribe of American Indians on the Upper Orinoco in Venezuela. Very appreciable diversities have been recorded for several loci (R^2 from 0 to 0.11, MS from 0 to 0.21, P^1 from 0.34 to 0.70, Jk^a from 0.38 to 0.84). Cavalli-Sforza ascribes the heterogeneities to random genetic drift rather than to local differences in natural selection. Neel interprets "these differences as primarily reflecting the manner in which new villages originate." However that may be, the role of gene exchange between local populations as a genetically leveling factor is quite apparent.

Gene Gradient or Clines

The above are examples of *micro*geographic differentiation of Mendelian populations of the human species. Man is a social animal; his settlement patterns and the reproductive biology of human populations sometimes permit genetic difference to arise among geographically adjacent population nuclei. We now turn to the *macro*geographic differentiation, which is quantitatively but probably not qualitatively distinct from the microgeographic. For some tens of thousands of years, mankind has been a nearly cosmopolitan species. Human populations live under a variety of physical and cultural environments. Although man has always been a wanderer, and his traveling ability has increased enormously owing to the progress of his technology, some populations are separated by distances so great that the gene exchange between them is limited. Populations that inhabit different continents and parts of the same continent often differ in many genes; as a consequence, they differ in many morphological and physiological characteristics. In other words, mankind is an aggregate of racially distinct populations.

The genetic nature of the race differences is only beginning to be understood. The classical race concept, in anthropology as well as in biology, was typological. Every individual of Negroid, Mongoloid, Caucasoid, and even Jewish and Nordic "races" was a variant of a mythical "type" of his race.

Operationally, this concept led to characterization of the racial types by systems of average values of measurements and observations made on samples of populations living in, or descended from ancestors who resided in, different territories, or belonging to different castes, or speaking different languages. The more separate measurements or traits went into the construction of a racial type, the more valid and reliable it was supposed to be. This typological approach reached its extreme, almost a *reductio ad absurdum,* in the attempts discussed above to find different racial types among individuals of the same population, and even among members of the same family.

Genetics has gradually made the ineptitude of typological approaches evident to increasing majorities of anthropologists. Mendelian populations should be described in terms of the incidence in them of separate characteristics, and ideally of the alleles of variant genes. Boyd's (1950) pioneering attempt to carry out such a description using the then-known blood genes met a skeptical reception, although the race classification he arrived at was little different from some then-current typological ones. The two decades since have increased greatly the available information, and also revealed complexities that were not so clearly apparent before.

When the frequencies of gene alleles or of separate phenotypic traits are plotted on maps (see examples in Mourant, 1954; Mourant et al., 1958; Lundman, 1967), one finds as a rule gradients (clines) of increasing or decreasing frequencies toward or away from some centers. Thus, the allele I^B of the OBA blood group system reaches frequencies between 25 and 30 percent in central Asia and northern India.

Its frequencies decline westward to 15 to 20 percent in European Russia, 5 to 10 percent in western Europe, and even lower in parts of Spain and France. The frequencies also decline southeastward, practically to zero among Australian Aborigines, northeastward to below 10 percent among the Eskimos, and to zero in unmixed Amerindians. The center of light skin and eye pigmentation is northwestern Europe; the pigmentation becomes darker eastward and especially southward, reaching maximum in subsacharan Africa, southern India, and Melanesia. Rohrer's index (body weight divided by the height cubed) reaches highest values among the Eskimos, and is lowest in southern Asia, Australia, and Africa.

Are any genetic differences among human populations qualitative, in the sense that some gene alleles are absent in some and reach 100 percent frequencies in other populations? As noted by Darwin, "Of all the differences between the races of man, the color of the skin is the most conspicuous and one of the best marked." Indeed (cases of albinism excepted), no native of subsacharan Africa is born as lightly pigmented as the natives of Europe, and no European develops as dark a pigmentation as an African. However, this skin color difference is due to additive effects of at least three, possibly twice as many, pairs of genes without dominance. Heritable skin color variations are found among Europeans as well as among Africans. One can well imagine that the skin color could be darkened considerably by selective breeding in a population of European descent, and lightened in a population of African descent. Whether or not the *intra*racial pigment variations are due to the same gene loci which are responsible for the *inter*racial differences is uncertain. One of the alleles of the Rh system (*cDe*) reaches frequencies above 50 percent in African populations, but it occurs with low frequencies, generally below 5 percent, elsewhere in the world, in individuals without known African ancestry. An allele of the Diego locus seems to be lacking among Europeans and is frequent among Amerindians, although not reaching 100-percent frequencies among the latter. An allele of the Duffy system has frequencies above 90 percent among Negroes in western Africa, but is also found with low frequencies among Europeans.

Our tentative conclusion, subject to modification by future findings, must be that qualitative differences, in the sense defined above, are absent among human populations. This is in no way contradicted by our ability to distinguish any individual native in, for example, Congo or Ghana from any Scandinavian, and both of these from any native of eastern Asia. The reason is, of course, that the populations native in these countries differ in frequencies not of a single gene but of many genes. Typological race concepts must be replaced by populational ones. Individuals are not accidental departures from their racial types. On the contrary, interpopulational racial differences are compounded of the same genetic variants which are responsible for genetic differences among individuals within a population, and even among siblings and parents and children.

Racial Differences and Races Named

The apparently endless variety of living beings is as fascinating as it is perplexing. There are no two identical humans, as there are no two identical pine trees, or two Drosophila flies, or two infursoria. The runaway diversity of our perceptions is made manageable by means of human language. Classifying and giving names to classes of things is perhaps the primordial scientific activity. It may antedate the appearance of *Homo sapiens,* and it is bound to continue as long as symbol-forming animals will exist. Biologists and anthropologists describe and name the complexes of organisms which they study in order to identify for themselves, and let others know, what they are talking and writing about.

Human beings whom we meet, and about whose existence we learn from others, are numerous and diversified. We have to classify them and attach recognition labels to the classes. So we distinguish the speakers of English, Russian, Swahili, and other languages; college students, industrial workers, and farmers; intellectuals and the "silent majority," and so on. Those who study human physical, physiological, and genetic variations among men find it convenient to name races. Races can be defined as arrays of Mendelian populations belonging to the same biological species, but differing from each other in incidence of some genetic variants.

The question is often posed: Are races objectively ascertainable phenomena of nature, or are they mere group concepts invented by biologists and anthropologists for their convenience? Here we must make unequivocally clear the duality of the race concept. First, it refers to objectively ascertainable genetic differences among Mendelian populations. Second, it is a category of classification which must serve the pragmatic function of facilitating communication. One can specify the operational procedures whereby any two populations can be shown to be racially different or racially identical.

The populations contain different arrays of genotypes if racially different, or similar arrays if racially identical.

Racial differences exist between populations regardless of whether or not somebody is studying them. Yet this does not mean that any two genetically different populations must receive different race names. For example, Cavalli-Sforza (1959) has found no significant genetic differentiation between inhabitants of villages on the densely settled Parma plain; he did find such a differentiation between the villages in the more sparsely settled mountains (see above). Racial differences are, therefore, ascertained among the latter but not among the former. It would nevertheless not occur to anyone to give race names to the populations of every mountain village. The village names are adequate labels for the populations that live in them.

How many arrays of populations in the human species should be provided with race names is a matter of expediency. Already, Darwin noted that "Man has been studied more carefully than any other organic being, and yet there is the greatest possible diversity among capable judges" concerning the number of races recognized and named. Different authors referred to by Darwin named from 2 to as many as 63 races. The incertitude is undiminished today. Hardly any two independently working classifiers have proposed identical sets of races. This lack of unanimity has driven some modern "capable judges" to desperation. They claim that mankind has no races, and that the very word "race" should be expunged from the lexicon. This proposal is often motivated by a laudable desire to counteract notorious racist propaganda. But will this be achieved by denying the existence of races? Or will such denials only impair the credibility of the scientists making them? Is it not better to make people understand the nature of the race differences, rather than to pretend that such differences are nonexistent?

To give an example of a race classification by an author fully conversant with modern biology and anthropology, Garn (1965) recognizes 9 "geographical races" and 32 "local races," some of the latter being subdivisions of the former. The geographical races are as follows:

1. Amerindian
2. Polynesian
3. Micronesian
4. Australian
5. Melanesian-Papuan
6. Asiatic
7. Indian
8. European
9. African

Among the local races not included in his major geographical list, Garn distinguishes three interesting categories —Ainu and Bushmen are "long-isolated marginal," Lapps, Pacific Negritos, African Pygmies, and Eskimos are "puzzling, isolated, numerically small," and American Blacks, Cape Colored, Ladinos, and Neo-Hawaiians are "hybrid local races of recent origin." On the other hand, Lundman (1967) recognizes only 4 main races—white, yellow, red (Amerindian), and black; his 16 subraces correspond only in part to Garn's local races. If one of these classifications is accepted as correct, must the other necessarily be incorrect? This, I believe, need not be so; we should rather ask which classification is more convenient, and for what purpose.

In sexually reproducing and outbreeding organisms, every individual can usually be recognized as a member of one and only one species, or else as a hybrid of two species. Adherents to the typological race concepts believed that the same should be true of races. Every individual, excepting only the progeny of interracial crosses, should be classifiable as belonging to a certain race. This is not so, because species are genetically closed, while races are genetically open systems. For example, there is no individual whose belonging to the species man or the species chimpanzee could be called in question. These species do not exchange genes. There are, however, many local populations in northwestern Asia intermediate between the white and the yellow, and in northern Africa intermediate between the white and the black races. This does not mean that individual members of these intermediate populations necessarily have two parents belonging to different "pure" white, black, or yellow races. Whole populations are intermediate. Sometimes this is due to secondary intergradation (Mayr, 1963), i.e., to interbreeding of populations which became genetically distinct in a near or remote past. This is, in fact, the origin of Garn's "hybrid local races." More often the intermediate populations are autochthonous; primary intergradation is a result of gene diffusion taking place while the racial divergence of the populations is in progress, as well as after the populations have diverged. The gene gradients or clines result from both primary and secondary intergradations.

Gene gradients make it only rarely possible to draw a line on the map to divide the regions of different races. Race boundaries are more often blurred than sharp. Worse still, gradients of the frequencies of different genes and traits may be only weakly or not at all correlated. This can easily be seen on maps that show the frequencies of various traits in human populations, such as different blood antigens, pigmentation, and stature (see, e.g., the maps in Lundman, 1967). Human races are not discrete units imagined by typologists, so some disappointed typologists have seen fit to draw the radical conclusion that races do not exist.

Let us take a closer look at the situation. If gene or character gradients were uniform, gene frequencies would increase or decrease regularly by so many percentages per so many miles traveled in a given direction. With uniform gradients, race boundaries could only be arbitrary. However, often the gradients are steeper in some places and are more gentle or absent elsewhere. Consider two gene alleles, A_1 and A_2, in a species with a distribution area 2,100 miles across. Suppose that for 1,000 miles the frequency of A_1 declines from 100 to 90 percent; for the next 100 miles from 90 to 10 percent; and for the remaining 1,000 miles from 10 to 0 percent. It is then reasonable and convenient to divide the species into two races, characterized by the predominance of A_1 and A_2, respectively, and to draw the geographic boundary between the races where the cline is steep.

Why are the gene frequency gradients gentle in some and steep in other places? The steepening of the gradients usually coincides with geographic and environmental barriers that make travel difficult. Barriers to travel are also barriers to gene diffusion. Newman (1963) has analyzed the human racial taxonomy in a thoughtful article. His general conclusion is that ". . . there are valid races among men, but that biology is only beginning to properly discover and define them. . . . I consider some of Garn's races probably valid, others probably invalid, with still others in the 'suspense' category for lack of adequate data." He validates Garn's Asiatic, African, and Amerindian races as showing good trait correlations in such visible traits as pigmentation, hair form and quantity, nose and lip form, cheek bone prominence, eyelid form, and general body shape. European, Indian, and Australian are "unwarranted abstractions," on account of the high variability and discordance (lack of correlation) in the geographical distribution of many traits. Melanesian, Polynesian, and Micronesian are in the "suspense" category.

Adherents of the "no races" school argue that one should study the geographic distributions of genes and character frequencies, rather than attempt to delimit races. The truth is that both kinds of studies are necessary. Gene and character geography is the basis of the biological phenomenon of racial variation; classification and naming are indispensable for information storage and communication. The fact that races are not always or even usually discrete, and that they are connected by transitional populations, is in itself biologically meaningful. This is evidence of gene flow between races being not only potentially possible but actually taking place. Gene flow between species, however, is limited or prevented altogether. To hold that because races are not rigidly fixed units they do not exist is a throwback to typological thinking of the most misleading kind. It is about as logical as saying that towns and cities do not exist because the country intervening between them is not totally uninhabited, or that youth and old age do not exist because there is also middle age.

Race Differences as Products of Natural and Sexual Selection

A century ago Darwin felt "baffled in all our attempts to account for the differences between the races of man." In particular, natural selection can hardly be invoked, because "we are at once met by the objection that beneficial variations alone can be thus preserved; and as far as we are enabled to judge (although always liable to error on this head) not one of the external differences between the races of man are of any direct or special service to him." He put more faith in sexual selection: "For my own part I conclude that of all the causes which have led to the differences in external appearance between the races of man, and to a certain extent between man and the lower animals, sexual selection has been by far the most efficient." Of the 828 pages of *The Descent of Man, and Selection in Relation to Sex,* part I, "On the Descent of Man," takes 250 pages, and part II, "Sexual Selection," more than twice as many.

It is almost incredible that, a century after Darwin, the problem of the origin of racial differences in the human species remains about as baffling as it was in his time. Several circumstances have conspired to make it so. The chief one was that, until less than a generation ago, the leading anthropologists assumed that race differences are mostly adaptively neutral, and consequently made little effort to discover their selective values. Radical changes in human environments brought about by cultural developments made the problem particularly difficult to approach; a genetic trait may have played an adaptive role a million years ago which was quite different from its role ten thousand years ago, and that again may have been different from what it is at present. Finally, by a curious twist of reasoning, the doctrine of human equality seemed to exclude the possibility of differential genetic adaptedness.

The adaptive significance of even so obvious a trait as skin pigmentation has not been fully clarified. The notion that a dark pigmentation is protective against sunburn is very old, and made plausible by the fact that dark-skinned races are (or were) inhabitants of the tropics, and light-skinned ones of temperate and cold countries. This rule is not free of exceptions; the Indians of equatorial South America are not particularly dark, and some of the natives of northeastern Siberia are at least as dark as those of Mediterranean Europe. These exceptions have been "explained" by assuming that the relatively light people in the hot countries and the relatively dark ones in cold countries are recent immigrants, or that Indians of equatorial America live mostly in forest shade rather than in the open. It has also been supposed that light skins facilitate the synthesis of vitamin D in countries with little sunshine, while dark pigmentations protect against excessive amounts of this vitamin where the sunshine is abundant. There is good evidence that light skins are more prone to develop skin cancers owing to sun exposure than are dark skins. Still another surmise is that dark skin pigmentation may facilitate absorption of solar radiation "where energy must be expended to maintain body temperature, at as dawn and dusk in otherwise hot climates" (Hamilton and Heppner, 1967). Finally, a dark skin may give a protective coloration to a hunter stalking game or escaping from predators.

The above hypotheses concerning the adaptive significance of pigmentation are not mutually contradictory or exclusive, and yet their multiplicity attests to the inadequacy of our understanding of the adaptive role of even the most conspicuous of all human racial differences. A considerable amount of careful study has been devoted to the physiology of human populations adapted to certain particularly rigorous environments, such as Indians of the Andean Altiplano (cold, low oxygen supply), and Eskimos of the Arctic (Baker and Weiner, 1966; Baker et al., 1967). Riggs and Sargent (1964) and others compared the reactions of young black and white males to exertion under humid heat conditions. Some statistically assured differences in the expected directions have been found, but it is not ruled out that a part of these differences may be the product of physiological adaptation to the environments in which the person grew up.

Racial differences in the incidence of various blood groups have long been a challenge to those who believe that all racial differences must be established by natural selection. There is no doubt that certain pathological conditions (e.g., duodenal ulcers) occur more often in carriers of some blood antigens than in others, but it is questionable whether these correlations are even in small part responsible for the racial differences. Attempts to correlate the blood groups with resistance to some infectious diseases, such as plague, smallpox, and syphilis, have thus far been unconvincing (a review in Otten, 1967).

Sexual selection "depends on the advantage which certain individuals have over other individuals of the same sex and species, in exclusive relation to reproduction" (Darwin, 1871, Vol. I, p. 256). In our present view, the difference between the natural and the sexual selections is not fundamental. The selection coefficient, i.e., the difference between the Darwinian fitnesses of different genotypes, measures the relative rates of transmission of certain components of these genotypes from generation to generation. It is of lesser consequence, though certainly not immaterial, that the differential gene transmission is in some instances due to greater success in mating, while in others it is caused by differential mortality, or fertility, or greater speed of the development, or anything else. Genetic variants which are favored by the balance of all these causes will increase, and those disfavored will diminish in frequencies in the populations. Lessened success in mating may be compensated by a greater viability or fertility, or vice versa.

That sexual selection, in the classical Darwinian sense, occurs in man is clear enough. Although almost everybody in primitive societies has an opportunity to mate and produce offspring, socially more influential and more prosperous individuals may not only have access to more mates but be able to provide better conditions, which increase the probability of survival of their offspring to maturity. Good evidence of this has been provided, for example, by Salzano et al. (1967) and Chagnon et al. (1970) for Xavante and Yanomama, two of the surviving primitive tribes of South American Indians. In both tribes, as Salzano et al. say, "Whereas women are uniformly exposed to the risk of pregnancy and rarely fail to reproduce, men, on the other hand, are characterized by an appreciably higher variance in their reproductive performance." In one of the villages studied two headmen have sired approximately one-fourth of the total population.

Some forms of physiological sterility of females as well as of males are genetic. Genetic conditioning of the psychological variables which predispose individuals to spinsterhood, bachelorhood, or to prolificity in technologically advanced societies is another matter, reliable data on which are almost totally lacking. It is, for example, an open question whether homosexuality has an appreciable genetic component. However, if the existence of such genetic conditioning were proven, its bearing on race differentiation would still be in doubt. Genetically caused partial or complete sterility, better known in Drosophila than in human populations (see Marinkovic, 1967), is a part of the concealed genetic load; when the components of this load become overt, they come under control of the normalizing natural selection. Normalizing selection can hardly bring about appreciable racial differentiation. What interests us is to what extent the racial divergence of populations is brought about by directional selection, of either the sexual or the natural kind (Dobzhansky, 1970). In other words, one wishes to know not only whether a given genetic trait is influenced by selection, but also, and this is a more difficult problem, why different variants of this trait are favored in different populations. The present state of knowledge in this field is quite unsatisfactory.

Race Differences and Random Genetic Drift

The genes of the two Xavante chiefs mentioned above, who have sired about one-quarter of their village population, became more frequent in that population than the genes of the less prestigious inhabitants. Let it be noted that this is true of the genes which might facilitate access to chieftainship, as well as of genes quite irrelevant in this respect. Every chief, like any other individual, has a constellation of genes somewhat different from other chiefs or other individuals. The populations of villages containing exceptionally prolific individuals become, for that reason, genetically differentiated from one another. This has been observed among the

Xavantes and Yanomamas by the authors cited above, and by Birdsell (1972) among aboriginal Australians. Nor is such differentiation found only among primitive tribes. Glass (1954) and Steinberg et al. (1967) observed it among certain religious isolates in America; although the people involved presumably adhere to strict monogamy, variations in the numbers of children per family inevitably occur. In the course of time, these variations add up to diversification of the gene frequencies, i.e., to incipient racial diversity. In contrast to selection, which is a directional and deterministic process, here we are dealing with stochastic or random genetic processes. Random genetic drift, random walk, founder principle, and non-Darwinian evolution are some of the names applied to these processes. Can they help to explain the origin of race differences in mankind and other species? Race differences induced by natural selection have biologically a very different meaning from those induced by random genetic drift. Natural selection makes the populations differentially adapted to different environments. In other words, race differences which arose by selection are, or at some time were, adjusted to life in some kind of different circumstances. This is not necessarily the case with differences due to drift. At least initially, the populations may be adaptively equivalent. To be sure, the selection may act on the originally neutral differences and make them parts of adaptively integrated hereditary endowments. Selection and drift may in the course of evolution be interrelated.

The importance ascribed to stochastic versus deterministic processes in evolution has undergone an interesting cycle. It would be out of place to discuss the matter here in detail, but a brief account is in order. The prestige of natural selection as an evolutionary agent was at its lowest ebb during the early part of the current century, while genetics was groping for formulation of its basic concepts. Between 1926 and 1932, Chetverikov, Fisher, Haldane, and Wright arrived, largely independently, at the biological, or synthetic, theory of evolution, in which the deterministic processes are regarded as fundamental. However, Wright also recognized the importance of random genetic drift, sometimes called "the Sewall Wright principle." He did not, as he was erroneously accused by some writers, regard this principle as an alternative to or a substitute for natural selection, but as an agency, the interactions of which with natural selection have important evolutionary consequences.

Some authors, mostly nongeneticists, sought to utilize random genetic drift as an explanation of the origin of all kinds of differences between organisms to which they could not readily attribute survival value. Race differences in man are in this category. Heuristically, this was a tactical error. To investigate the effects of a trait on the Darwinian fitness of its carriers, it is more expedient to entertain as a working hypothesis that this trait may have such effects. A reaction against this error was strong in the forties, fifties, and the early sixties. Although the theoretical possibility of random drift could not be denied, its role in natural populations, and hence in evolution, was declared negligible. The pendulum has now swung back. King and Jukes (1969) published their provocative paper on non-Darwinian evolution, and Kimura and Crow (1969) and Kimura and Ohta (1969) have for quite different reasons urged that most mutational changes have no effects on fitness, and hence must be engaged in random walk in the population gene pool. Non-Darwinian evolution is now rather in fashion, especially among molecular biologists.

King and Jukes named their theory non-Darwinian because it postulates that many, if not most, evolutionary changes are not the products of natural selection. This name disregards more than a century and a half of the history of biology, which saw several non-Darwinian, i.e., nonselectionist, theories of evolution. To mention some of them: the Lamarckisms of Lamarck and of the turn-of-the-century Lamarckians (which are not the same theory), orthogenesis of Eimer, nomogenesis of Berg, aristogenesis of Osborn, as well as several frankly vitalistic notions. Darwin was himself in part a non-Darwinian, since he credited (mistakenly, we believe) the inheritance of acquired modifications as an important adjunct to natural selection. Moreover, in the *Origin of Species* he wrote: "Variations neither useful nor injurious would not be affected by natural selection, and would be left a fluctuating element, as perhaps we see in the species called polymorphic." This is as good an anticipation of the modern non-Darwinism as could be imagined.

What are the arguments in favor of the random walk being an important source of evolutionary changes? Briefly, King and Jukes argue that because of the degeneracy (redundancy) of the genetic code, about a quarter of the base substitutions in the DNA-RNA chains will give the same amino acid, and thus leave the protein coded by the gene unchanged. The relative frequencies of the 20 amino acids in diverse proteins of diverse organisms agree, with a conspicuous exception of arginine, with the statistical expectation based on the assumption of random permutations of the nucleotides in DNA. Comparison of homologous proteins in different organisms shows different numbers of amino acid substitutions, the numbers being allegedly proportional to the time elapsed since the separation of the phyletic lines leading to the organisms compared in paleontological history. This is interpreted to signify that the amino acid and nucleotide substitutions occur at uniform rates in time, as might be expected if they occurred at random, not under control of natural selection.

Unfortunately for this theory, the rates of changes are distinctly different for different proteins; some proteins conserve their amino acid sequences more tenaciously than others. This may mean that the nucleotide sequences in some genes are inherently more mutable than in others. Far more plausible is that natural selection discriminates rigorously against most changes in some genes, but is more permissive with other genes. More detailed comparisons of homologous proteins, such as cytochromes-c or hemoglobins, show that some parts of the molecules are constant in quite diverse organisms, presumably because they are essential for whatever physiological functions these proteins perform. Interesting attempts have been made to fit the numbers of changes in other parts of the same molecules to expectations based on the Poisson series, i.e., on the assumption that these changes are fixed at random, uncontrolled by natural selection. The results have been interpreted as confirming the hypothesis of random fixation, but the possibility that they are due to selection has not, in my opinion, been ruled out. There may be all degrees of likelihood that the substitutions of the amino acids at different positions will be accepted and promoted by natural selection. Since changes that obviously do not fit the Poisson series are deliberately left out of consideration, the fit of the remainder may be spurious.

Gene changes which are perceived as racial characteristics are obviously those which produce at least some visible, phenotypically detectable effects. Changes that do not alter the gene products are scarcely relevant to the present issue, however interesting they may be in other contexts. Of course, some phenotypically detectable changes may also be neutral with respect to fitness, and will represent the "fluctuating element" postulated by Darwin. Their frequencies will then be subject to random genetic drift. Given very long time and many generations, some of the changes will be lost in some populations, fixed in others, and remain fluctuating in still others. The question is whether the time intervals which must be assumed are not prohibitively long. Kimura and Ohta (1969) have shown that the average number of generations intervening between the origin and fixation of an adaptively neutral mutant gene is close to $4N_e$, where N_e is the genetically effective population size.

To evaluate the possibility that random genetic drift may have been responsible for racial differences, one would need to know at least the orders of magnitude of the N_es at different stages of human evolution. Reliable data are unfortunately lacking. Hordes, tribes, clans, and even nations may well have suffered reductions to small numbers of individuals owing to starvation, epidemics, warfare, and other calamities, and then expanded again when circumstances became propitious. A tribe may undergo fission, or give rise to small groups who move off and found a new tribe of their own. The absolute as well as effective sizes of the founder populations may be of the order of tens or even fewer. The founder variety of the genetic drift (i.e., unique or repeated reductions, rather than continuously small effective populations) may well be responsible for the intertribal genetic differences, examples of which have already been given.

That the 9 major, or for that matter the 32 local, races in Garn's classification could have arisen through the operation of the founder principle seems unlikely. Although all-or-none differences between human races are few, gene frequency differences are often considerable, and, more important, involve many genes. Even if the Amerindian, Asiatic, European, African, and other races were supposed to have descended from single pairs of progenitors, these racial Adams and Eves could not have been sampled from the same population.

The genetic divergence of the races must have been a gradual process; inasmuch as the developing races lived on different continents and under different environments, natural selection had ample opportunities to promote genes which fitted the human populations to different conditions of life. How much differentiation in neutral genetic traits could have occurred at that stage? The effective populations of the primordial races must have been in hundreds of thousands or in millions, and the average length of a generation hardly less than 20 years. The time intervening between the origin and fixation of a neutral genetic variant would then be $80N_e$, in millions or tens of millions of years. Any gene exchange between the diverging races would greatly lengthen the time, or make it infinite. These are, as indicated above, time estimates from the origin of a genetic variant to its fixation in a population. If races differ merely in the relative frequencies of certain gene alleles, neutral with respect to fitness, such differences might arise more rapidly.

Are Races of Man Genetically Adapted to Different Ways of Life?

The species mankind, in common with many, perhaps a majority of, animal and plant species, is genetically differentiated into major races (subspecies), minor races, and local populations of various orders. Because man is the only animal species having culture, certain kinds of differentiation are peculiar to him—linguistic, religious, and socioeconomic isolates, some of which may not be genetically identical. As pointed out above, most or all of this genetic differentiation is quantitative rather than qualitative. Racially distinct populations of *Homo sapiens* usually differ in frequencies of variable genes, rather than one race having 100 percent of a gene variant which another race lacks altogether. The genetic differences between human races can therefore be said to be relatively minor; in many species of animals the races have diverged genetically much further, and are on the threshold of becoming derived independent species.

All men are genetically "brothers under the skin." It is nevertheless legitimate to inquire to what extent genetic differences between populations are reflected in their health, environmental preferences, and capacity for mental development and for becoming members of different cultures. What is the biological, evolutionary function of race formation in the living world as a whole? It is differential adaptedness of subdivisions of a species for living in different geographic and ecological circumstances. Does this apply to human races?

We have discussed the roles of natural selection and of random genetic drift in the origination of race differences. Differences induced by selection make the population adaptively different in some respects, at least where and when the selective process operates. The random drift may, as a first approximation, be regarded as "noise" in evolutionary adaptive processes. It is most likely that race differentiation in man arose neither by selection nor by drift alone, but by interaction of these evolutionary forces. It would nevertheless be foolhardy to attempt to dichotomize racial differences into adaptively meaningful and adaptively neutral ones.

The possibility must be considered that genetic differences between the races and populations were adaptive in the past but are neutral at present. They may have been induced by natural selection in response to the environments in which the populations lived. But human environments change radically because of the adoption of different ways of life, particularly because of cultural and technological innovations. The selection may act in a different way, or may no longer be effective in changed environments. The skin color differences are a case in point. As shown above, it is most probable that skin pigmentation was adjusted by natural selection to the climatic characteristics of the territories in which the human races were formed. But how much adaptive importance does the skin pigmentation have at present, when most people have most of their body surfaces covered with clothes, and live in artificial dwellings rather than outdoors? It may well be that for most people skin pigmentation is now an adaptively neutral characteristic.

Other examples of changing selection pressures may be found among genetic defenses against infectious diseases. Such genetic defenses became racial traits in territories in which a given infectious disease is pandemic. A classical example is the gene for the sickle red blood cell condition (hemoglobin S). Though this gene results in fatal anemia when homozygous, the heterozygous carriers not only survive but are relatively protected against some tropical forms of malarial fevers. The gene is absent in countries where these fevers do not occur, but reaches high frequencies (up to 30 percent) in some populations of tropical Africa exposed to malarial infections. Here, then, is a racial trait which was maintained by natural selection as an aid for survival in malarial environments. With malaria brought under control and perhaps approaching eradication, the S gene has lost its adaptive function. Of course, no population was ever homozygous for this gene, since it is lethal when homozygous; in the absence of malaria it is at best neutral, or mildly deleterious, when heterozygous. Its frequencies are dwindling, and it may eventually be eliminated altogether.

By far the greatest attention, and also some violent emotional reactions, are aroused by studies on possible race differences in mental traits, especially in the so-called "intelligence." Are people of all racial stocks born equal, or are some intrinsically superior and others inferior? In the first chapter of this book arguments have been presented to show that the emotional reactions unleashed by studies on the "intelligence" of human races are due to sheer misunderstanding. We need only reiterate the highlights of these arguments. Equality should not be confused with biological identity, or genetic diversity with inequality. Human equality and inequality are not statements of observable biological conditions. They are policies adopted by societies, ethical principles, and religious commandments.

People can be made equal before the law, equality of opportunity may be promoted or guaranteed, human dignity equally recognized, and human beings can be regarded equally God's sons and daughters. To be equal, people need not be identical twins, i.e., need not be genetically alike. And vice versa, regardless of how similar or different they are genetically, individuals can be treated unequally, as social superiors and inferiors, masters and servants, aristocrats and plebeians. There is no reason why monozygotic twins must necessarily be social equals, even though they are genetically as nearly identical as two individuals can be. People can be made equal or unequal by the societies in which they live; they cannot be made genetically or biologically identical, even if this were desirable. In principle, human diversity is as compatible with equality as it is with inequality.

Any two human individuals, identical twins excepted, carry different sets of genes. This has traditionally been stressed by partisans of social inequalities, and deemphasized by champions of equality. It should be the reverse—equality is meaningful only because people are not identical. Like illness, genetic lottery is no respecter of the social position or rank of the parents. Owing to gene recombination in the progeny of highly heterozygous individuals, genetically well- and poorly-endowed children are born to parents of either kind. This does not deny the existence of some positive correlations between the genetic endowments of parents and offspring. The fact that these correlations are far from complete is, however, socially and ethically no less important than that the correlations are there.

The above is a necessary preamble to the substantive issue: Is there incontrovertible evidence of genetic differences between human populations, such as major and minor races, in mental traits, particularly in their capacities for intellectual development? The literature of the subject is as formidable in bulk as it is uncritical and unreliable. Most of it deals with ostensibly a single trait, the IQ, which in reality is a compound of several abilities that may well be genetically independent in various degrees. Furthermore, only a small minority of racial stocks have been studied, perhaps because of insuperable difficulties of devising intelligence tests that would be applicable to people speaking different languages and brought up in different cultural traditions. Whether such culture-free, or culture-fair, tests can be constructed is an open question, but it is certain that existing ones fall short of this desideratum in various degrees. There is always a danger that the tests will be biased in favor of the race, social class, culture, and subculture to which the test constructors themselves belong. A fair comparison becomes less and less possible as the groups tested differ more and more in socioeconomic, linguistic, traditional, and attitudinal backgrounds. Attempts have been made to correct for these sources of error, but with scant success.

By far the greatest number of studies deal with only two population groups—the blacks and the whites in the United States. The so-called Coleman Report (1966) is exceptional in also including IQ statistics for American Indians, Puerto Ricans, Mexican-Americans, and Oriental populations living in the United States. The plethora of papers comparing the IQ test results of whites and blacks have been uncritically compiled by Shuey (1966), and analyzed by Jensen (1969). There is no doubt that the average IQ scores of the blacks tend to be lower than those of the whites. The means for either race vary in different parts of the country, obviously depending on the socioeconomic and educational opportunities of the inhabitants of different states. In some northern states the blacks have shown higher mean scores than the whites in some southern states. However, most often the black mean is found to be 10 to 20 IQ points below the white. Jensen takes 15 points as a fair estimate of the average difference. It happens that the standard deviation (square root of variance) for the white populations is also close to 15 points. Of course, the black and white distributions overlap, and about 15 percent of the individual blacks score above the white average, while many whites score below the black average. According to the Coleman Report, the American Indians, Puerto Ricans, and Mexican-Americans are intermediate between blacks and whites, and Orientals are about equal to whites in the mean IQ score (the amount of data concerning these "ethnic" populations is a small fraction of those for the blacks and whites).

The key problem is, of course, whence comes the observed difference between the IQ means for blacks and whites? This problem has provoked ample polemics, which show no sign of subsiding. As shown in the first chapter of this book, differences in IQ scores between individuals within a population have an impressively high heritability, estimated by Jensen to be about 0.8 (80 percent). Racists have seized upon this figure as evidence of racial superiorities and inferiorities, arguing that since the heritability of the IQ variations is so high, differences in the IQ averages between races are fixed and irremediable. This is certainly unproven and unconvincing.

Jensen (1969) is fully aware of the fact that a heritability estimate for *intra*populational veriability does not necessarily tell us anything about the magnitude of the genetic component in an *inter*populational difference of means. Environments in which the racial groups live in the same country or state are appreciably and often drastically different. Even if the intrapopulational heritability were 100 percent, the interracial differences could be wholly environmental. Nevertheless Jensen argues, and rightly in my opinion, that it is not valid to attribute the interracial differences in IQ averages to undefinable differences between environments. For interpopulational, as well as for intrapopulational, differences in mean IQs, one should be able to specify just what environmental factors produce a specific effect. He appeals to studies which have tried to equate the environments of the blacks and the whites by comparing population samples of ostensibly equal socioeconomic status. When this is done, the IQ average differences diminish but do not disappear entirely. Jensen takes this as evidence of a strong genetic component in the differences between the black and white populations.

Bodmer and Cavalli-Sforza (1970), among others, have pointed out the inadequacies of equalization of the socioeconomic status as a way toward equating the total environments in which the races live. In their words:

> It is difficult to see, however, how the status of blacks and whites can be compared. The very existence of a racial stratification correlated with a relative socioeconomic deprivation makes this comparison suspect. Black schools are well known to be generally less adequate than white schools, so that equal numbers of years of schooling certainly do not mean equal edu-

cational attainments. Wide variation in the level of occupation must exist within each occupational class. Thus one would certainly expect, even for equivalent occupational classes, that the black level is on the average lower than the white. No amount of money can buy a black person's way into a privileged upper-class white community, or buy off more than 200 years of accumulated racial prejudice on the part of the whites, or reconstitute the disrupted black family, in part culturally inherited from the days of slavery. It is impossible to accept the idea that matching for status provides an adequate, or even substantial, control over most important environmental differences between black and white.

One can only conclude that the degree to which differences in the IQ arrays between races are genetically conditioned is at present an unsolved problem. I fully agree with Bodmer and Cavalli-Sforza that "we do not by any means exclude the possibility that there could be a genetic component in the mean difference in IQ between races. We simply maintain that currently available data are inadequate to resolve this question in either direction." Assume for the sake of argument that some part of the average difference between the IQs of the blacks and the whites is genetic. Would it follow that the blacks are an inferior and the whites a superior race? Would it be a vindication of the racists in Alabama, South Africa, and elsewhere? Certainly not. Two basic facts refute the racists: the broad overlap of the variation curves for IQs and other human abilities, and the universal educability, and hence capacity for improvement, however that be defined.

We may accordingly agree with Darwin (1871), that "Although the existing races of man differ in many respects . . . yet if their whole organization be taken into consideration they are found to resemble each other closely in a multitude of points. . . . The same remark holds good with equal or greater force with respect to the numerous points of mental similarity between the most distinct races of man. The American aborigines, negroes and Europeans differ as much from each other in mind as any three races that can be named; yet I was incessantly struck, whilst living with the Fuegians on board the 'Beagle,' with the many little traits of character, shewing how similar their minds were to ours; and so it was with a full-blooded negro with whom I happened once to be intimate."

Races of Man and Breeds of Domestic Animals

In conclusion, consideration must be given to the argument which is the more misleading since it is superficially so plausible. Races of animal and plant species, of free-living as well as domesticated forms, develop differential adaptedness to the environments in which they live, or to the employments for which they are used. In particular, breeds of domestic animals differ, often quite strikingly, in their structural as well as behavioral characteristics.

Consider the numerous and diverse breeds of dogs, many of them specialized for different uses, with behaviors suitable for their employment. Thus shepherd dogs learn to herd sheep and cattle, scent hounds and bird dogs to find game, hunting dogs are used for pursuit, terriers for attack, and toy and lap dogs for companionship with humans. There is no doubt that these very different forms of behavior are genetically conditioned, although at the same time not only dogs but even wolves, which are their wild ancestors, possess the potentiality of being trained in different ways and of changing their behaviors accordingly (Scott and Fuller, 1965; Scott, 1968; Woolpy and Ginsburg, 1967). If the behavior of dog breeds and of breeds of other domesticated species is very strongly conditioned, why would man's races not follow this rule of genetic conditioning? Even some eminent geneticists who should have known better have been led astray by such reasoning (e.g., Darlington, 1969, 1972). Modern technologically advanced societies have been invented and built by a minority of human breeds. It is likely that the "lesser" breeds do not possess genetic aptitudes sufficient not only to create and manage but even to be members of these advanced societies.

The above argument is fallacious because it fails to take into consideration the unique and basic characteristic of human evolution (Dobzhansky, 1962, 1972). The cardinal distinction between mankind and all other forms of life is that man's adaptedness depends primarily on his cultural rather than on his genetic inheritance. Culture is acquired by each individual through learning, and is transmitted by instruction, chiefly, though not exclusively, by means of a language consisting of socially agreed-upon symbols. To adapt to new environments, mankind changes mainly its cultural inheritance, rather than its genes, as other organisms do. Of course, genes and culture are not independent but interdependent. It is man's genetic endowment which makes him able to think in symbols, abstractions, and generalizations. The potentiality of cultural evolution, which is uniquely human, has developed through the evolution of his gene pool. But the contents of his gene pool do not determine the contents of his culture. By way of analogy, genes give man his ability to speak, but do not decide just what he shall say on a given occasion.

The basic, and unique, capacity of man is his genetically established educability by means of symbolic language. This educability is a species trait common to all races and all nonpathological individuals. Its universality is no more surprising than that all people have body temperature and the pH of the blood varying only within narrow limits. Both educability and symbolic language became universal human traits because survival and success in man-made environments depended on possession of these traits. Nothing of the sort happened in any other wild or domesticated animal species. By contrast, genetically fixed specializations in both body structure and behavior have often been deliberately built into different domestic breeds.

In sum: breeds of domestic animals often differ in behavior, and the differences are genetically more or less rigidly fixed. Their behavior is a part of the complex of characteristics which make a given breed suitable for performance of a certain kind of work or function. The kind of behavior exhibited, as well as its degree of fixity, are induced by the artificial selection which the owners or masters of the animals practiced, deliberately or unwittingly, in the process of formation of a given breed. The evolutionary pattern of the human species is quite different. Natural selection has unrelentingly favored the ability of human beings to learn and to modify their behavior depending on the circumstances of their upbringing and social conditions in the midst of which they find themselves. This is precisely the opposite of selection in breeds of domesticated animals. Furthermore, selection for trainability and cultural receptivity has been going on not in some populations and races but in the whole human species, and uninterruptedly ever since the inception of humanity and of its dependence on culture as a method of adaptation to and control of the environment. Two million years and 100 thousand generations are probably conservative estimates of the duration of this selective process. The evolutionary uniqueness of the human species should not be underestimated.

3

EPILOGUE: MAN'S IMAGE

ABOUT THREE CENTURIES AGO, Pascal described the human condition with a lucidity and poignancy never since equaled:

> When I consider the short duration of my life, swallowed up in the eternity before and after, the little space which I fill, and even can see, engulfed in the infinite immensity of spaces of which I am ignorant and which knew me not, I am frightened, and am astonished at being here rather than there; for there is no reason why here rather than there, why now rather than then. Who has put me here? By whose order and direction have this

From Ben Rothblatt, ed., *Changing Perspectives of Man* (Chicago: University of Chicago Press, 1968), pp. 175–190. Reprinted by permission.

> place and this time been allotted to me? The eternal silence of these infinite spaces frightens me.

Whether the silence of the infinite spaces is more or less frightening to our contemporaries than it was to Pascal is hard to tell. The spaces still know us not, but we begin to know something about the spaces. By whose order this place and time have been allotted to us has, however, become, if anything, still more mysterious.

Objects most remote from us yet discovered in the universe are galaxies some five billion light-years away. The mysterious quasars (quasi-stellar objects), or some of them, may be as remote, but their nature and remoteness are still under dispute among cosmologists. This is a remoteness which staggers the imagination; the radiation from these objects reaching us today left its source billions of years ago. The universe is believed to have started in a cosmic explosion which made the universe "expand," or rather caused its different components to fly apart in all directions with colossal speeds. The date of this explosion, and consequently the supposed age of the universe, is estimated to be on the order of 10 to 15 billion years. These estimates tend, however, to be lengthened rather than shortened by newer discoveries.

The number of galaxies in the universe visible in the 200-inch telescope is estimated to be close to one billion. Our galaxy is merely one of these, yet it may contain between one million and 100 million planetary systems. One of these includes a medium-sized planet which we inhabit. The supposition that the planet earth is in any way unique or exceptional or privileged seems far-fetched to many scientists. It is, however, the only one known for certain to have a tiny proportion of its mass involved in a process called life. Moreover, the diversity of living beings is very impressive. There are at least two million kinds, or species, of life on earth at present, and there were more in the past, which became extinct.

The Problem of Extraterrestrial Life

Speculation is rife concerning the possibility that there may be life of some sort on other planets, in other planetary systems, and in other galaxies. Some authorities go so far as to proclaim it a certainty that life not merely could but must have arisen in many places in the universe. More than that, sentient and rational beings must have evolved on many planets where there is life. In other words, "We are not alone." The name "exobiology" has been invented for the study of the assumed extraterrestrial life. The problems of exobiology cannot be adequately discussed here; I realize that the following remarks may do injustice to the ingenious speculations advanced in this field. I cannot, however, help wondering if the exobiologists may not turn out to be high-powered specialists on a nonexistent subject. The stock argument in favor of the existence of life in many places in the universe runs about as follows: Although the critical step from the nonliving to the living may be a rare and improbable event, there are some 100 million planets in our galaxy on which this step coud be made, hence it must have been made on several or even on many. This argument is not really convincing, however, because nobody knows for sure just how probable or improbable the event may be under various circumstances. It is certain that the event happened at least once—on earth. The evidence that it was not a unique event is yet to be obtained—it cannot be taken for granted.

Let us, however, assume for the sake of further argument that life did arise in many places, and moreover that it was life based on nucleic acids and proteins, in other words, life chemically of the same kind as that on earth. This granted, it far from follows that such life must have evolved elsewhere as it did on our planet, let alone that it must have produced humanoid organisms. Evolution is principally adaptation to the environment; however, even if the environments somewhere happened to be much like, though of course not identical with, those on earth, a reenactment or repetition of the terrestrial evolutionary history has a probability very close to zero. This is because biological evolution is not predetermined to achieve any particular form of adaptedness to the environment. It has a range of possibilities that is virtually unlimited.

Evolution is a creative process which is most unlikely to occur two or more times in the same way. Man was not contained in the primordial life, except as one of an infinitely large number of possibilities. What these other unrealized possibilities might have been we probably shall never know. And yet, the origin of man was not an accident either, unless you choose to consider all history, including biological history and that of human societies, states, and nations, as series of accidents. This is a possible view, but not an appealing one. It is far more meaningful to describe biological and human histories as successions of unique events, each event being casually related to what went on before and to what will follow in the future, and yet nonrecurrent. George Simpson (1964) gave arguments essentially similar to the above in a brilliant chapter entitled "The Non-prevaence of Humanoids," that is, nonprevalence anywhere except on our planet. Our species, mankind, is almost certainly alone in the universe, and to that extent our planet is also unique.

To recognize this "aloneness" is not necessarily to experience the Pascalian "fright" and "astonishment." Quite the opposite. The space which mankind fills, and the duration of its existence so far, are indeed very small compared to the now known "immensity of spaces." The messages that we may wish to send describing human activities on earth may have to travel billions of years at the speed of light to reach the quasars and the remotest galaxies, and there is probably nobody there to receive these messages. Does it mean that all our doings, both those of individuals and of the human species as a whole, are mere whiffs of insignificance? Not at all; because it is unique, the career of the human species here on earth may be of cosmic significance. The idea need not be a wildly conceited delusion. Our species may well be alone in having discovered that the universe and all that it contains, including mankind, is a changing product of evolution. It is neither size nor geometric centrality in the solar system, or in our galaxy, or in the universe, that makes the planet earth so important. It is that the flames of self-awareness, of death awareness, and of evolutionary awareness have been kindled here on earth and probably nowhere else.

Evolution and Man's Image

The image of man as seen by Pascal and his contemporaries and successors is different from that emerging from evolutionary science. The difference becomes understandable when viewed against the background of the history of science and its philosophical implications since Copernicus, Galileo, Newton, and Darwin. Here again I am forced to be too brief and, I fear, too dogmatic. The pre-Copernican man felt certain not only that he was the heart of the universe but that the universe was created for him and because of him. The earth was the hub of several concentric spheres: those of the moon, the sun, the planets, and fixed stars. God watched the smallest happenings on earth from somewhere up above. The interior of the earth contained an elaborately engineered hell; a man could avoid becoming its resident in perpetuity only by good behavior during his brief sojourn on the earth's surface, and by the intercession of the properly constituted ecclesiastic authorities. With travel difficult and slow, the earth seemed to be very large. It shrank progressively as it was gradually explored and as travel became easy and rapid. It is quite small in the age of jet aircraft. But whether large or small, the earth existed for man and for the realization of God's mysterious plans for man's salvation.

All these arrangements did not make man free of anxieties. He faced the *mysterium tremendum*—why has God arranged things as he has? This was, however, just one extra mystery—the greatest one to be sure—but mysteries were all around, from the vagaries of weather to the behavior of one's friends and enemies. All these things were the doing of spirits, good or evil. Though spirits were more powerful than men, men were not entirely defenseless against them, because one could secure the assistance of some spirits against others.

The development of science changed the situation. The mystery seemed to recede, but in fact it was relegated to the beginning of the world. Copernicus, after him Kepler and Galileo, and still later Newton, together with their many followers and successors, changed the image of the universe and of man. The earth is a smallish planet revolving around a much grander sun. Instead of the celestial spheres there is only the endless void, in which other planets, suns, and galaxies are as tiny islets on an infinite ocean. Man is lost in cosmic spaces. It is not, however, the dimensional smallness of man that really matters. It is rather the mechanical and inexorably deterministic nature of the universe, and finally of man himself, that changes man's image. Celestial phenomena are calculable and predictable, provided that one has discovered the precise and eternal laws which they obey. Biological and psychological phenomena are less predictable, but only because they are much more complex and the laws governing them are yet to be discovered. Descartes decided that the human body was as much a machine as a clock or other "automation," although he still believed that man had a nonmechanical soul. Others found the hypothesis of soul to be superfluous. Man is a machine, and that is that.

God was found to be another superfluous hypothesis. To be sure, Newton and many other scientists tried to hold on to their religions. Newton thought that the planets were hurled into their paths initially by God. But subsequent to this divine act at the beginning, the planets follow their proper orbits, according to immutable laws and without further guidance. The deists thought that God was the original creator and lawgiver of the universe. Having created the universe and set it in motion, God found it so well made that his presence became no longer essential. Instead of mysteries, we have the laws of nature. Some people thought that God reserves the right of occasional miraculous intervention, temporarily abrogating the very laws which he himself has formerly established. To others, such behavior appears unseemly for the all-wise and omniscient creator. It is more convenient to imagine him as a sort of absentee landlord who lets things take their "natural" courses.

Mystery driven out through the front door tends to creep in through the back door. Has the creator and lawgiver arranged things really well? If he is credited with the order, beauty, and goodness in the world, he must by the same token be responsible for the disorder, ugliness, and evil. The machinery of the world has serious flaws, and this is a mystery defying comprehension. An absentee-landlord god can hardly be prayed to, since he is unable or unwilling to intervene to change the causal sequences which bring about events.

To this is added the hopelessness of determinism. As stated by Laplace, the doctrine of determinism is essentially that if one knew the position and speed of every particle in the universe at any single instant, and if one could submit this knowledge to analysis, one could predict all future events and also retrodict all past events. Although this statement contains two pretty vertiginous "ifs," determinism is an explicit or implicit faith which is the basis of scientific activity. It leads, however, to an embarrassing inference: there is nothing new in the world, because all that ever happens was predestined from the beginning. No human effort, or absence of effort, can change anything, because the effort or its absence is equally predestined. This is a far stronger fatalism than the fatalism sometimes (and mostly wrongly) ascribed to oriental philosophies.

Darwin has been called the Newton of biology, although the Copernicus or the Galileo of biology would perhaps be a better characterization. There is as yet nothing in biology analogous to, say, the laws of gravitation; the Newton of biology may be yet to come. To say this is not to underestimate Darwin's contribution. He has shown that the biological species, including man, have not appeared ready-made; their multifarious structures and functions are not mere whims of nature or of a creator. Every living species is a descendant of ancestors unlike itself, and generally more unlike the farther back in time one looks. It is probable, though not certain, that all beings now alive are descendants of one primordial life which appeared some four billion years ago. Presumed remains of living beings three and one-half billion years old have recently been found. The organic diversity is a consequence of adaptation to different environments; the endless variety of bodily structures and functions makes possible an endless diversity of modes of life. There are so many kinds of organisms because they can exploit more fully than any single organism conceivably could the diverse opportunities which an environment offers for living.

Evolutionary Uniqueness of Man

The human species has evolved a unique way to cope with its environments. This way is culture. Culture is not transmitted from generation to generation by the genes, although its biological basis is so transmitted. Culture has been called "superorganic," although it surely rests on an organic foundation. Man is an animal, but he is so extraordinary that he is much more than an animal. Darwin and his successor evolutionists have thus extended to the living world, and even to the human world, the principles which were shown to be supremely efficient in the study of the physical world. Biology has by now exorcised the ghost of vitalism, which wanted to see in life something radically incommensurable with the rest of nature. Mechanism has triumphed in biology. This triumph was what Darwin and the evolution theory were, and still are, mainly acclaimed for. There is, however, another aspect to evolutionism which may be at least equally and possibly more important. It sees the whole universe, and everything in it, in the process of change and development. The universe is on its way to somewhere. Where is it going?

The grandeur of the Newtonian image of the universe was in its serene constancy and the precision of its laws. Planets and their satellites follow their orbits again and again, in predictable fashion. Moreover, since Newton accepted the traditional creation date as well as the apocalyptic prediction of the end of the world, there was little opportunity for change either in the past or the future. The laws of the conservation of mass and of energy were discovered later; here was a break in the constancy, however—although energy is conserved, it undergoes a directional change because of entropy.

What biological evolution is all about, however, is not constancy but change. Darwin and his successors have shown that the living world of today is different from what it was in the past, and that it may become different again in the future. Mankind proved to have a hitherto quite unsuspected kind of history, the history of its slow emergence from its animal ancestors, in addition to the recorded history of patriarchs, kings, battles, and empires. While recorded history goes back only a few thousand years, biological history extends somewhere between one and a half and two million years. But even this history is short relative to that of the life from which man came, which took perhaps four billion years. And back of that are more billions of years, when the universe existed without either life or man.

I do not wish to be understood as claiming that it was Darwin who made evolution into a universal principle. In point of fact, it was recognized before Darwin that the planetary system has had a history of origin from the primitive sun, or from a mass of matter which gave origins both to the sun and to the planets. Human history has been studied at least since Herodotus and Thucydides; late in the eighteenth century Condorcet ascribed to it a directional character—from a primitive barbarianism to an earthly paradise of perfect enlightenment. Darwin's theory of biological evolution is, however, the keystone of the evolutionary conception of the world, beginning with the evolution of the cosmos and culminating in the evolution of mankind. Modern cosmology is evolutionary cosmology. Even the atoms of the chemical elements, hitherto symbols of indivisibility and unchangeability, proved to have had an envolutionary history. In the homely language of some modern cosmologists, the atoms were "cooked" in the explosion at the start of cosmic evolution, and are still being cooked in the furnaces of the interior of the sun and the stars.

It has been urged by some authorities that the term "evolution" should be restricted to biological evolution only. I do not share this view, because it seems to me important to convey the idea that change and development are characteristic of nonliving as well as of living matter and of human affairs. This does not prevent one from recognizing that the processes of cosmic, inorganic, or geological evolution are different from biological evolutionary processes. The causes of biological evolution must be looked for in heredity, mutation, and natural selection. None of these is found in nonliving systems, and the analogies which some authors have attempted to draw are at best remote. Other analogues of heredity, mutation, and natural selection have been claimed in human social and cultural evolution with, I fear, even less success. These analogies are more often obfuscating than enlightening.

Nor can I see much of an advantage in the views expounded so brilliantly by such philosophers as Whitehead and Hartshorn. They like to ascribe to inorganic systems, and even to atoms and subatomic particles, some rudiments of life, individuality, and, further, of consciousness and volition. It is almost needless to say that there is no positive evidence, either compelling or presumptive, of any such biological and human qualities in nonliving systems. Even as a speculative possibility these views do not seem to me attractive. They really amount to a denial of anything substantially new ever arising in evolution. They are most nearly analogous to the early performistic notions in biology; some eighteenth-century biologists believed that a sex cell contains a "homunculus," a tiny figure of man. This seemed to make the problem of development very simple—the homunculus had only to grow in size to become an adult man, and a corresponding miniature in an animal sex cell had to grow to become an adult animal of the proper species. But this simplicity was deceptive, since it made the problem of development of succeeding generations insoluble. One had to believe that homunculi contained second-order homunculi, these had third-order homunculi, and so on. An analogous difficulty arises with the "minds" of atoms. It might seem at first that human mind could simply evolve by growth of the atomic mind. Human mind is, however, somehow associated with the human brain, and where are the brains of atoms and electrons?

The most interesting aspect of evolution is precisely that it creates novelties. From time to time it transcends itself, i.e., produces novel systems with novel properties—properties which the antecedent systems did not have even as tiny germs. Emergence of the living from the nonliving and emergence of humanity from animality are the two grandest evolutionary transcendences so far. Teilhard de Chardin was the evolutionist who had the courage to predict further transcendences, mankind moving toward what he called the megasynthesis and toward Point Omega, this last being his symbol for God. Here is evidently a borderland, in which Teilhard's science has collaborated with his mystical vision. I am not planning in the present discussion to take you on an excursion in this borderland of prophecy.

As already stated, we do not know for sure whether the transcendences of the nonliving to life, and of animal to man, have taken place solely on this planet earth or in many places in the universe. Perhaps some positive information bearing on this issue will come from the progress in space travel. Be that as it may, we do have conclusive enough evidence that these three kinds of evolution—inorganic, organic, and human—have happened here on earth. These three kinds of evolution are not independent of each other; they are rather the three stages of the single evolution of the cosmos. By calling them stages, I do not mean to suggest that cosmic evolution stopped when the biological phase started, or that biological evolution stopped when the human phase began. On the contrary, the three kinds of evolution are not only going on, but are connected by feedback relations. For example, geography influences the living things which inhabit a given territory; in turn, vegetation, animals, and especially human activities have now become geographic and even geologic agents. Human cultural evolution influences mankind's genetic endowment, and vice versa. In recent years there have been publicized some alarmist views asserting that human genetic endowment is in a process of degeneration, and predicting dire consequences for the future. This matter cannot be adequately discussed in this book; I believe that the dangers have been exaggerated, and in any case the situation is not beyond possible control.

The evolutionary view of the world does not abrogate the classical Newtonian mechanistic view. The change which evolutionism makes is nevertheless of greatest importance for man's views of himself and of his place in the universe. The classical conception stressed the essential permanence of things, at least for the duration of the world's existence. The evolutionary conception emphasizes change and movement. The preevolutionary world view did not, of course, deny all change, but the changes were usually represented as cyclic, and the world as a whole did not go anywhere in particular. Spring, summer, autumn, and winter return again and again at the appointed times; people are born, grow, build families, get old, and die, and a new generation goes through the same succession of stages; plants and animals, like people, produce generation after generation; heavenly bodies follow their orbits again and again; mountains rise, are eroded away, become submerged in the sea, rise up again, and so on. But to translate a French adage, the more things change, the more they remain the same.

Constancy, lack of change, and regular recurrence seem to be reassuring and comforting to many people. "Like the good old days" is a compliment tinged with nostaliga. Change brings insecurity; one has to become adapted, adjusted, or reconciled to altered situations. Yet changelessness, or eternal repetition or return, is the acme of futility. A world which remains forever the same is senseless. It is what Dostoevsky called a "devil's vaudeville." All the strivings and struggles which a person, or a generation, has to go through are in vain because the next generation, and the one after that, and so on, ad infinitum, will have to go through the same struggles all over again.

What difference does the idea of evolution make? Quite simply, it is this: the universe is not a status but a process. Its creation was not something which happened a few thousand years ago, before any of us were born and could have influenced it in any way. The creation is going forward now, and may conceivably go on indefinitely. The view that "there is nothing new under the sun" is in error. In the past there were an earth and a sun different from the present ones, and there will be a new earth and a new sun in the future. An important role in this forward movement belongs to the phenomenon called life, and to one particular form thereof called mankind, which exists as far as we know only on a single and not otherwise remarkable planet.

Evolution as a Creative Process

The evolution of life is remarkably rapid, measured on a cosmic time scale. Ten million years ago, the oceans and mountains, the moon, the sun, and the stars were not very different from what they are now, but the living beings inhabiting the earth were rather unlike the present ones. Ten thousand years ago mankind was quite different from what it is now, while except for the destruction of some biological species, the biological world was pretty much what we now observe. Evolution is a creative process; the creativity is most pronounced in human cultural evolution, less in biological, and least in inorganic evolution.

A creative process by its very nature always risks ending in a failure or being stranded in a blind alley. Every biological species is nature's experiment, essaying a new mode of living. Most species eventually prove unsuccessful and become extinct without issue. Yet some, a minority, discover new or superior ways of getting a living out of the environment which is available on earth. These few lucky discoverers inherit the earth and undergo what is technically known as adaptive radiation. That is, the surviving species differentiate and become many species again, only to repeat the process of discovery, extinction, and new adaptive radiation. Yet this is not another specimen of eternal return. New adaptive radiations do not simply restore what there was earlier; the new crop of species may contain some which have achieved novel or surer ways of remaining alive, or have discovered previously unexploited niches in the environment and have thus augmented the living at the expense of the nonliving.

The trial-and-error process of proliferation of ever-new species and of disappearance of the old ones has achieved remarkable successes. Biological evolution has transcended itself by giving rise to man. Mankind as a species is biologically an extraordinary success. It has gained the ability to adapt its environments to its genes, as well as its genes to its environments. This ability stems from a novel, extragenetically transmitted complex of adaptive traits called culture. Culture leads to still another kind of discovery, discoveries of knowledge, which can be transmitted to succeeding generations again by means of the extragenic processes of instruction and learning. One of the discoveries which became known is the discovery of evolution. Man knows that the universe and life have evolved, and that mankind entered this universe by way of evolution. With perhaps a bit too much poetic license, it has been said that man is evolution having become conscious of itself. It is no exaggeration, however, to say that having discovered evolution, man has opened up a possibility of eventually learning how to control it.

The enterprise of creation has not been completed; it is going on before our eyes. Ours is surely not the best of all thinkable worlds, and, we hope, not even the best of all possible worlds. Man is constantly asking whether his existence, and that of the universe in which he finds himself, has any sense or meaning. If there is no evolution, then all is futility—human life in particular. If the world evolves, then hope is at least possible.

An uncomfortable question inevitably presents itself at this point. Can science ever discover meaning in anything, and is a scientist entitled even to inquire about meanings and purposes? To a rigorous mechanicist who does not wish to think in evolutionary terms, such words as meaning, improvement, progress, and transcendence are meaningless noises. Everything in the world, including myself, is an aggregation of atoms. When this aggregation disaggregates, the atoms will still be there and may aggregate into something else. Is there an objectively definable difference between an object of art and a junk heap? If a virus and a man are nothing but different seriations of the nucleotides in their DNAs and RNAs, then all of evolution was a lot of "sound and fury signifying nothing."

One of the exasperating phenomena of the intellectual history of mankind is politely called "the academic lag." This crudely mechanistic world view was acceptable in science chiefly during the eighteenth and nineteenth centuries. It had justified itself by having given a powerful impetus to scientific discovery. It is now being displaced by the evolutionary world view. Yet the representatives of what C. P. Snow has referred to as literary or nonscientific culture have only recently discovered that the world is nothing but an aggregation of atoms. It is a curious experience to hear an artist argue that a junk heap is, indeed, no less worthy of aesthetic appreciation than is the "Venus de Milo," because both are matter wrought into arbitrary shapes; or to have an eminent musician declare that the atonality and certain other characteristics of avant-garde music are merely recognition of the Copernican discovery that man is not the center of the universe; or to read in a book by an intellectual pundit that "something pervasive that makes the difference, not between civilized man and the savage, not between man and the animals, but between man and the robot, grows numb, ossifies, falls away like black mortified flesh when techne assails the senses and science dominates the mind."

In reality, science is neither a villain debasing human dignity nor the sole source of human wisdom. In Toynbee's words:

> Science's horizon is limited by the bounds of Nature, the ideologies' horizon by the bounds of human social life, but the human soul's range cannot be confined within either of these limits. Man is a bread-eating social animal; but he is also something more. He is a person, endowed with a conscience and a will, as well as with a self-conscious intellect. This spiritual endowment of his condemns him to a life-long struggle to reconcile himself with the Universe into which he has been born.

The fact that the universe was evolved and is evolving is surely relevant to this reconciliation. The advent of evolutionism makes it necessary to ask a new question which simply could not occur to those who believed that the world is created once and for all, stable and changeless.

The question is: Where is evolution going? This question can be asked separately about the three known kinds of evolution—cosmic, biological, and human. It has also been asked about evolution as a whole, because the three kinds of evolution can be viewed as the constituent parts, or stages, of a single all-embracing process of universal evolution. This universe, so formidable and so beautiful, is in a process of change. It may be that evolution is merely drifting at random, and going nowhere in particular. There is, however, also a possibility, for which no rigorous demonstration can be given, that universal evolution is one grand enterprise in which everything and everybody are component parts. Whose enterprise is this, and with what aim and for what purpose is it undertaken? The four centuries of the growth of science since Copernicus have not dispelled this mystery; the one century since Darwin has made it more urgent than ever.

What role is man to play in evolution? Is he to be a mere spectator or, perchance, the spearhead and eventual director? There are people who will shrug this question off, or recoil from it, considering it an exhibition of insane arrogance. Since, however, man is one and presumably the only rational being who has become aware that evolution is happening, he can hardly avoid asking such questions. The issue involved is no less than the meaning of his own existence. Does man live just to live, and is there no more sense or meaning to him than that? Or is he called upon to participate in the construction of the best thinkable universe?

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INDEX