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Committee on Research in the Life Sciences

Report Panel #20: Biology and the Future of Man

Panel Members:

Th. Dobzhansky
Rene Dubos
D. R. Goddard
J. Lederberg
J. V. Neel
F. Notestein
R. R. Revelle
C. Stern (Chairman)

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BIOLOGY AND THE FUTURE OF MAN

The Nature of Man

The future of man will depend on many events, some consciously decided upon and others happening without intention. Social organizations through their political leaders will determine on peace or war, on the use of conventional or nuclear weapons, on the encouragement or discouragement of measures to limit the growth of populations, on the degree of increase in food production and on the conservation of a healthy environment or its degradation. These decisions will unconsciously affect the composition of the human species. Some groups which genetically differ from others will grow in numbers, others will decline either relatively or absolutely. Thus in the seventeenth century the Europeans and their descendants on other continents made up approximately 20 per cent of the world's population; in 1940 they represented nearly 40 per cent of all people. It appears that an opposite trend -- a relative increase of Asian and African people -- has set in more recently. Neither of these trends had been planned. Rather, they were the results of complex circumstances such as the opening up to immigration of sparsely inhabited continents, of the industrial revolution, of the introduction of contraceptive devices and of improvements in medical knowledge and of public health measures.

Man is a social being in two senses of the term social. He is social in his being part of the systems of social organizations which are the unique attributes of man, from the relatively primitive to the most elaborate social structures. He is social also in his being one of many animal species who have developed social systems such as small family associations, larger herds, packs, up to highly specialized communities such as are found among bees, ants and termites with their biological castes of queens, workers, males and soldiers.

Man is an animal in other ways as well. In form and function, development and growth, reproduction, aging and death he is a biological entity who shares the attributes of physical life with the millions of plant and animal species to whom he is related. This has been known since prescientific times. It became part of well established science long before the theory of evolution was proposed. It is the reason why studies of fungi and mice, flies and rabbits, weeds and cats and many other types of organisms all have contributed to understanding man and to improving his health and biological well-being, and why future studies with experimental organisms will have their bearing on man's own future.

Man's mental attributes form a superstructure which does not exist independently of his organismal construction. Human thought is based on the human brain, and the brain of each person is one of the derived, developed expressions of the genes which he inherited from his parents. Man's capacities are thus linked to his genes whose chemical molecular nature is now understood to a very high degree. Although the social creations of man have an existence of their own and are transmitted by social inheritance from generation to generation, they depend for their persistence and change on the genetic endowments of the biological human beings who are subjected to them and who at the same time make them possible.

The biological discoveries of the nineteenth and twentieth centuries presage further developments which will enable man to mold his own future evolution. The world of the highly planned and controlled test-tube babies of "Brave New World" which Aldous Huxley foresaw forty years ago is certain to become biologically feasible. There is, however, a time interval between feasibility and social adoption which may be very long. Social systems in spite of changes in some aspects have great inertia which is the more resistant to change the more a change would require abandonment of age-long practices. Nevertheless, it seems unlikely that the inertia of social systems will inhibit forever even the most fundamental changes, but such changes in attitude may relegate the human use of biological procedures to a very distant future, long after they have been tested in cattle, monkeys and apes. It is possible that this view of social inertia is based overly much on past experience. It may be argued that the radically increased opportunities for obtaining information on all kinds of subjects which are available to almost all members of modern populations will possibly greatly reduce social inertia, even to an undesirable or dangerous degree. This may be particularly true of the peer-oriented or "teen-age" cultures which seem to be a phenomenon of "advanced" societies. The strength of social inheritance from generation to generation may be much less in the future with the result that adoption of new biological technologies may be much more rapid than in the past.

In the following pages, biology and the future of man will be mostly considered for the short range period ahead as defined by the length of about two human generations or about half a century. Selecting a few examples, we may consider what is likely and what is unlikely to happen, what can be hoped for and what feared and what should be done.

In such considerations, man should be ultimately taken as inclusive of all human beings on our planet. The brotherhood of all men is not only an ethical imperative but biologically it is based on their common descent and on the magnitude of the shared genetic heritage. Actually mankind is divided into so-called nations which insist on their sovereign status and the short range future of man will be different from one so-called sovereign group to another. Our discussion, therefore, will mainly reflect the prospects in developed countries and regions.

War and the Future of Man

The considerations of the future of man which follow presuppose that mankind will not be subjected to a nuclear holocaust. If such an event would occur, the problems of retaining or reestablishing social organization, the breakdown of health services including the production of drugs, antibiotics and immunizing agents and the ensuing threat of world-wide epidemics would take precedence over all other aspects concerning biology and the future of man. It may well be that modern technology is powerful enough to make complete extermination of man a possibility. To accomplish such a deed would require not only overwhelming use of nuclear bombs over large areas of the globe but in addition a deliberate effort to distribute lethal fall-out radiation evenly over all inhabited regions. Barring such limitless designs, mankind would probably survive a nuclear war. Radiation biology has demonstrated that the acute dose of irradiation which kills human beings after momentary exposure is relatively low. Direct radiation from nuclear bombs would therefore take an immense toll, but the survivors would be able again to repopulate the earth. Those who survived the immediate impact of nuclear explosions would be subjected to chronic irradiation from fall-out which would likely lead to a variety of deleterious effects. In addition to the damage to their own bodies, the survivors would produce egg or sperm cells which as the result of radiation would contain many new mutations leading to abnormal offspring. Nevertheless, the radiation dose which the survivors would have received from the initial exposure and the accumulation of fall-out radiation might often be low enough to enable them to produce also normal appearing and functioning children, provided the survivors would still want to create a new generation.

Similar consideration may apply to the possibility of wide-spread use of biological warfare. The constructive understanding of life which Biology provides can now be used for wholesale destruction of life. All war in our time and in the future is liable to grow beyond control, whether it be conducted with physical, chemical or biological means or with combinations of all of them. A future for man can be assured only when the ultimate danger of modern war is fully recognized and mankind abandons warfare.

Biology and Medicine

The most immediate impact of biology on man takes place by way of medical procedures. Biological research and medical research are intimately intertwined and their discoveries often cannot be assigned clearly to one discipline or the other. The benefits of such studies apply to innumerable individual events, taking place before birth and extending through infancy, childhood and adulthood to old age. The prolongation of life expectancy at birth is one of the impressive over-all measures of the success of medicine. Nevertheless, it should be emphasized that even in affluent societies this prolongation is primarily due to a reduction if not a near abolition of infant mortality. Increases in life expectancy past the age of 45 have remained smaller although by no means negligible. Different medically advanced countries still have different life expectancies and infant mortalities. It is noteworthy and regrettable that the United States has not yet succeeded to equal the best records of other countries. Future advances in the control of disease will come from better epidemiological knowledge, improved control of the environment and deeper understanding of the regulation of life processes. Many of these advances will be based on applications of the fundamental information provided in recent years by molecular biology, the science which interprets all life processes in terms of individually simple interactions of molecules. Still other advances will come from pure technology applied to deficiencies in the function of whole organs. An artificial lung external to the body replaces the physical action of the muscles necessary for breathing, an artificial kidney serves as a chemical device for removing substances from the blood when the biological excretory organs cannot perform that function. Artificial blood vessels made of industrially manufactured tubing can serve as substitutes for defective natural vessels, and artificial hearts can, at least for some time, take over the pumping function of the inborn organ. And if artificial structures are at present still less adequate than natural ones, transplantation of organs from one person, alive or after death, to another offers another avenue to saving of life. Transplantation itself involves the serious problems of immunological incompatibility of the tissues of donor and host with the threatened subsequent rejection of the transplant as well as its causing reactions in the host. Modern biology, however, in experiments with chickens and mice and with cultured human blood cells is well on its way to learn how to minimize such antagonistic effects either by the right choice of relatively compatible tissue constitutions, by the production of immunological tolerance or by combination of both procedures.

These insights and techniques are capable of prolonging life beyond the normal span but they are creating great new difficulties. One of these is external and linked to social organization. It relates to the availability of the artificial machines, and the natural parts used in transplantation. It relates equally to the availability of physicians and specialized personnel required to apply the techniques of surgery and control of intricate instruments. Millions of individuals would profit from the transplantation of organs or from the use of the new spare parts but for years the supply will be inadequate to fill the demand. The ethical conflicts are crushing which the physician faces when he is forced to decide who is to benefit and who is to be denied vital help. At present the occasions for such decisions are still rare since the numbers of available natural organs or substitute technological "organs" are so limited. In the future, numerous new devices will be invented and the problems of assigning them to specific patients at the cost of withholding them from others will increase in frequency. Furthermore, even if such devices could be made available in large numbers, the cost of keeping a small fraction of the population alive may be so high in terms of the gross national product as to compete seriously with other needs for the well being of the population.

Another difficulty goes even deeper. Relatively little progress has been made in prolonging the adequate functioning of the human brain. The perpetuation of the physical workings of many parts of the body has not been accompanied by a perpetuation of its normal mental aspects. Here lies a great challenge for basic research and the beneficial application of the insights to be hoped for. Some of the best minds among biologists, psychologists and physical scientists have recently turned their efforts to neurophysiology and brain function. Their studies should help to understand the riddle of the physical basis of the mind as well as to discover fundamental procedures for alleviating the tragic situation of keeping the body alive without the full mental attributes which characterize a normal person. One may confidently expect progress in prolonging the physical and mental health of the aged but even then the problem of disharmonious functioning will be present at the end period of a more extended life span. Biology as the science of life has to be complemented by new insights in the biology of death. The application of such insights will intensify the concern with questions which already demand answers. How much is society justified in keeping the aged alive when all mental functions have ceased which distinguish human beings from vegetating bodies? Where is the limit of anguish and material burden which the relatives of such aged persons and which society at large can bear concerning a problem which is increasing in frequency and severity? Medical research in aging involves the whole range of biological phenomena, from a study of the molecular changes of such substances as the collagen in our connective tissues and bones to the study of the most complex functioning of the central nervous system with its basis for consciousness, learning, reasoning, memory and other psychological attributes. Support of research in aging and support of the aged cannot be considered separately from economic and demographic facts. The need for support of research which will benefit the physical as well as mental health of the new-born and that of young people in general may compete in terms of personnel and material resources with the requirements of research on aging. The need for dedicating large-scale support to children and adolescents may limit the support society can devote to keeping the aged alive beyond a reasonable state.

Genetic Diseases

The main illnesses of man have changed greatly in importance during the last hundred years. Infectious diseases have been combatted effectively as their biological nature became clarified. For example, malaria was recognized as being caused by mosquito-born protozoa, tuberculosis by bacteria, and influenza by viruses. Sulfa drugs and the antibiotics were found to kill the infectious agents without damaging the host. Other diseases, like rickets and scurvy, were shown not to be caused by the presence of an abnormal agent but by the absence of normally required substances, the vitamins. Recognition of needs for vitamins have greatly reduced such deficiency diseases. Many diseases which still plague man are "inborn errors" which, as the effects of abnormal genotypes, lead to gross congenital malformations or to subtle derangements of metabolism. Some of these inborn errors are now understood in biochemical terms. Phenylketonuria, to take a famous example, is an inherited condition in which an enzyme, formed in the liver of normal persons, is not synthesized in the liver of affected persons. A single kind of gene present in normals and absent in phenylketonurics is responsible for the difference. The result of the absence of the enzyme is an accumulation of a substance, phenylalanine, in the blood, which normally is transformed by the enzyme into some other substance. The accumulation results in brain damage expressing itself in mental defect. The gene effect can also be discovered soon after birth by the presence of an abnormal derivative of phenylalanine in the urine. It took twenty years to unravel the biochemistry and genetics of the disease. Only then did it become possible to devise a treatment for it. Phenylalanine is a constituent of proteins which are an essential part of our diet. If beginning with infancy a phenylketonuric individual is given a special diet very low in phenylalanine, development may proceed in improved fashion and the mental abilities of the child may approach normality.

It is hardly more than ten years since phenylketonuria has been treated this way and the last word has not yet been said about the degree of success. Nevertheless, phenylketonuria is an example of modern medicine's attack on genetic disease. Although the defective gene itself which is responsible for the absence of the enzyme cannot be cured, its effect can be circumvented. Such procedures have been termed euphenic, "eu" meaning well, and "phene" meaning appearance. Euphenics can overcome the ill effects of the genetic endowment to a greater or lesser degree. There are many ways for euphenic treatment of unfavorable genotypes. Thus, in diabetes, a genetic disease with apparently a more complex biological basis than in phenylketonuria, abnormalities in the production or utilization of the hormone insulin exist which result in defects of carbohydrate metabolism. In this case the defect is overcome to a considerable extent by furnishing the body with insulin from the outside. Or, in a congenital malformation such as cleft lip and palate, modern plastic surgery is able not only to save the life of severely affected infants but also to produce an esthetically acceptable appearance. It is clear that a euphenic solution has to be discovered separately for each genetic effect. Only a few such solutions have been found and further search will be an important area of biological efforts. Such work illustrates the fact, first clearly demonstrated in studies of plants and animals, that genetic determination of abnormalities does not imply an unchangeable fate. In man, many genetic errors may be made more or less innocuous by biomedical treatment. There is valid reason to expect that future work will greatly extend the range of euphenics to errors which are still beyond repair.

Early Environmental Influences

External conditions may not only ameliorate genetic defects, but they can also depress normal development. Expressed in a different way, inadequate environments may lead to defects in genetically adequate persons and improvement of the environment may tend to decrease defectiveness. One area to which interests have been directed more recently is that of the effects of early environmental influences.

As commonly used, the phrase "early influences" denotes the conditioning of behavior by the experiences of very early life. Early experiences, however, do more than condition behavioral patterns; they also affect profoundly and lastingly most biological characteristics of the adult. In animals and men, events occurring during the prenatal or early post-natal period condition the initial growth rate, maximum adult size, efficiency in utilization of food, resistance to malnutrition, to infection, and to other forms of stress.

Early influences affect some of the most obvious characteristics of human populations. Throughout the past century, for example, there has been a constant trend toward greater size, and earlier sexual maturity of children. This phenomenon was first detected in the United States, then in other Western countries; it is now particularly striking in Japan and in other areas that have adopted Western ways of life. Evidence for increased growth is provided by the greater heights and weights of children at each year of age; by the faster growth rates during adolescence for both boys and girls; and by the earlier age of the first menstrual period.

Early influences can also affect growth, mental ability, and health in a deleterious manner. This is readily documented in the underprivileged areas of the world and in the economically deprived segments of our own populations. Very high infant mortality, slow rate of growth during childhood and adolescence, physical and mental lethargy continuing throughout life, are among the pathological manifestations commonly observed in deprived social groups. These disorders are not racially determined. For example, they are found alike among the deprived Indians of Central America and among the populations of European origin who share the Indians' ways of life. In contrast, these disorders are rare among Indians and Latin people born and raised in social and economic environments similar to those now prevailing in the prosperous communities of the United States and Europe.

Epidemiological studies of human populations provide evidence that the most important effects of the environment are those experienced during early childhood. When environmental agencies act on the human organism before puberty, their anatomical, physiological, and psychological effects are to a large extent irreversible; the fact that the various tissues and organs develop at different rates after conception and birth accounts for the existence of several "critical" periods in giving complete or partial irreversibility to responses that the developing organism makes to environmental forces. In the human species, the critical periods for the development of the various mental capacities probably occur before the age of 6 - 8, a phenomenon of great relevance to the determination of "intelligence" in different socio-economic and ethnic groups. In contrast to the effects of the environment before the termination of critical periods, they are more likely to be reversible when experienced after the end of differentiation and development.

Practically all effects of prenatal and early post-natal influences so far recognized by clinical and epidemiological studies of human populations occur also in other animal species. A large variety of stimuli, acting on the pregnant animal during gestation, or on the young shortly after birth, can affect almost every type of phenotypic expression throughout adult life. This is true whether animals live under natural conditions or in the laboratory.

Exposure to toxic agents; malnutrition, undernutrition or overnutrition; overt or subclinical infections; "mothering" deficiency of the lactating dam; emotional disturbances of the mother or of the young; crowding, isolation and other forms of social deprivation -- are but a few of the variables that have been used to design experimental models for the study of the effects of early influences. The effects of these influences on adult life have been studied with regard to anatomical structures, physiological characteristics, metabolic activities, behavioral patterns, and learning ability. In all cases "critical periods" have been recognized, differing as to initiation and duration depending upon the nature of the early influence, and of the effect studied.

Many experiments have been made in various animal species, and they have led to the development of several reproducible models, but the body of knowledge concerning the effects of early influences is nevertheless extremely superficial and indeed episodic. Even the phenomena that have been most extensively studied -- such as imprinting, the fixation during a critical period of a young animal's life, of the stimulus which subsequently elicits a particular response -- are poorly understood even though highly reproducible in their details. In the absence of broad scientific generalizations, it is not possible at present to extrapolate from one animal species to another, let alone to man. Yet there is no doubt that early influences are of great importance in human life; knowledge of their potentialities points to the safest and most effective way of affecting the physical as well as mental development of man.

The study of the effects of early influences can be conducted at several different levels.

a) Epidemiological observations in man, taking advantage of the fact that the different human societies exhibit an extremely wide range of customs with regard to gestation, parturition, lactation, physical and behavioral management during the early postnatal period. Differences in social patterns can be considered as experiments on man, carried out without awareness of their consequences, that cry out for careful description and analysis.

b) Development and refinement of experimental models in various animal species. To yield the greatest scientific rewards, these models will have to use laboratory animals of known genetic and experiential history. It will be essential furthermore that these animals be kept under observation throughout their whole life span and preferably for several successive generations. Needless to say such longitudinal studies will require much improved animal quarters, extensive facilities for recording and retrieving information, and probably a new type of scientific organization.

c) Analysis of the mechanisms through which early influences exert their lasting effect. It is neither possible, nor necessary to discuss or even list here the many types of experimental approaches that will have to be followed in such analysis. It is worth pointing out, however, that understanding of the mechanisms through which early influences condition the fate of the adult will go far toward giving a new and more dynamic character to anatomical, physiological, metabolic, and behavioral studies. Environmental stimuli are most effective in shaping the phenotypic expressions of the genotype when they impinge on the organism during the early phases of its differentiation and development.

The Demographic Need for Biological Knowledge

It is now common knowledge that the upsurge in the growth of human populations constitutes one of the major problems for the immediate future of man. In view of the world's problems of population growth, it is difficult to exaggerate the urgency of deepening our biological knowledge of man and his environment. By the end of the century, a brief thirty-three years from now, there is every reason to expect that the world will have almost twice its present population. Unless forestalled by a worldwide holocaust, the world in the year 2000 will almost surely have not fewer than five billion people, and the number may well exceed seven billion. World population will rise from the present figure of 3.4 billion to seven billion even if the present rate of growth declines, and since the means for improving the control of disease are already at hand, the seven billion figure would be reached even if present birth rates were to be considerably reduced. This growth is occurring most rapidly in the newly developing nations where abject poverty is widespread, the mass of the population is uneducated, and the modern sectors of the economies are poorly developed.

Moreover, coming demands on the biosphere are not to be measured exclusively by the expected growth of numbers. The present population is badly nourished, and popular aspirations for improved living conditions are high. Even a doubling of per capita consumption of food, clothing and shelter would leave present aspirations unfulfilled. If political order is to be maintained, it is not unreasonable to expect that the demands on the biosphere by the end of the century will be from four to six times those of the present. The problems of attaining such increases become staggering when we realize that the end of the century is so close that this year's infants will then be in the heart of their childbearing period. Moreover, a reasonable regard for the human heritage requires that the needs be met without despoiling either the quality of man or the material base from which he draws his life.

Clearly a catalog of needed knowledge is a catalog of an entire field -- the nature of man and his modes of change, the extra-human biosphere, and its interaction with man and with the physical environment. But this is just another way of saying that man's destiny turns on his knowledge of himself and of his total environment -- inanimate, biological and social. In the face of a desperate situation, almost nothing becomes irrelevant in the entire spectrum of basic and applied science.

In the long run it is clear that: (1) population growth cannot continue indefinitely, and (2) if we can have a world in which the major populations have been brought to a high level of education and scientific achievement, the ultimate constraints to population growth will not appear until populations become larger than they are now. Such a world might, and probably would, find it desirable on humane and esthetic grounds to check its growth far short of the numbers that could be supported in considerable affluence by economies that continue to develop their basic and applied sciences. To such a world a knowledge of the gene pool, and of its potentialities for change, might be more important than anything else, because in the last analysis man's destiny lies in his nature.

But today's most urgent problems are not those of a world of highly educated and prosperous populations. They are the problems of moving from our present position of widespread poverty and mass illiteracy to a high stage of worldwide education and prosperity. To do so we must survive the crisis of population growth with sufficient political and social coherence to permit the sensible application of our developing science. The difficulty about crises is precisely that they place such a heavy discount on matters of future as compared to those of immediate relevance. Many of these immediate problems lie in the social, economic and political fields, but it is to the biological aspects of the emergency problems that our attention is here directed.

The first and most basic problem is that of food. The facts need not be spelled out. It is only necessary to note that: (1) most of the world is undernourished; (2) populations in the Americas south of the U.S., in Asia, and in Africa are growing at between 2.3 and 4 per cent per year; and (3) agricultural production is barely keeping pace with population growth and in some instances is falling behind. Production per acre has been increasing rapidly in the highly developed areas of the world, but it has been rising very little in the underdeveloped nations. In the latter, gains in production have come primarily from the extension of acreage rather than from increased product per acre. Moreover, the constraints to the extension of acreage are becoming all too visible in many of the most densely settled parts of the world.

These facts suggest that: (1) there indeed will be starvation with tragic checks to population growth unless there is a prompt and major rise in production, and therefore (2) the most urgent need is for the application of existing knowledge rather than for the development of basic science. Indeed, the practical application of our present basic science would go far toward coping with the problems of food supply during the present century. The problems are applied ones of a practical nature but they are nevertheless squarely in the scientific field. Basic theory does not bring increased production without a great deal of scientific work on local soil and water, crop management, animal husbandry, pest control and fertilizer. Our basic science gives us the principles and tells us how to go about learning to apply them, but it still does not tell us in precise and local terms how to do the multitude of things that must be done. There is a vast amount of particular and detailed scientific work that must be done, much of it at the local level, before our basic science can yield essential gains in the production of food and fiber. The emergency need in agriculture is for great increases in applied work and in training for such work.

The fact that much of the basic sciences is a product of a small number of nations and civilizations does not mean that the basic sciences cannot be learned, developed and applied by other populations. Even though we have no means at present of comparing the genetic endowments of different ethnic groups, it is clear that great reservoirs of trainable genotypes exist in all of them. The shortage of brain power in the world at large, which can be applied to the immediate problems of agricultural production is not due to biological limitations of genetic endowments in different human groups, but to the limitations of education. Each area is potentially able to produce the numerous persons who are needed to explore and solve the specific problems which the region poses. These problems, obviously, are not restricted to agriculture. A corps of local specialists is equally needed so that each population may share in the beneficial results of industrial and scientific technology.

The emergency problem of population growth involves much more than merely increasing agricultural production. The constraints to population size are all too visible in the traditional self-sufficient agrarian society. Such societies have never been able to combine high population density with good health and relative freedom from poverty. On the other hand, it is hard to specify the limits to the density of population that can be supported in health and prosperity by a highly educated population making sophisticated uses of inanimate energy and raw materials, and continuing to develop both its basic science and technology. One would hope that such a world population would want to limit its size before it was compelled to do so to protect either its health or its prosperity. The emergency problem is not that of keeping the population below some particular figure. The emergency problem is that of attaining as rapidly as possible high levels of education, science and technology for a majority of the members of the human race.

If this estimate of the situation is correct, the problem is not that of population size itself but of the speed of modernization and the extent to which it is checked by the speed of population growth. The speed of modernization turns on many factors, among other things on the national and international allocation of resources as, for example, space, war, schools and factories. But basically it also depends, even down to quite local levels, on the extent to which the growth of production outstrips that of population. Investment in development can be made only after the current costs of growth have been met.

One way to find income for development is to increase production. Another way is to decrease reproduction, and both ways are clearly needed. The two are not quite on an equal footing. It is not difficult to imagine too much production of the wrong kind, but it is difficult to imagine too much production as such. On the other hand, some methods to decrease the rate of population growth that would be undesirable in nature, in amount, or both are all too evident. As a practical matter we need not be concerned, because no one will advocate reducing growth by increasing death rates for his own group, and in the newly developing countries there is no practical possibility of bringing rates of natural increase below one per cent per year in the near future Moreover, populations that have learned to reduce their fertility to the point where even with good health growth amounts to only one per cent should encounter no substantial difficulty in reaching a stationary position if that is clearly desirable. It may be justifiably asked, however, how many countries can be expected to do this soon enough.

If the foregoing is correct then the second most important emergency problems of a biological nature are those concerned with a reduction of human fertility. In the long run birth rates must come down if death rates are to stay low, and in the short run lower fertility would speed the process of modernization by widening the difference between the growth rates of population and of production. Reductions of the birth rate in the under-developed countries have an additional advantage. High birth rates produce high proportions of young people. In fact, virtually every country with 40 or more births per 1000 population has more than 40 per cent of its total population at ages under 15. In the advanced countries low birth rates give between 25 and 30 per cent of the total at ages under 15. A reduction in birth rates brings down rates of growth and reduces the proportion in the ages of childhood dependency. Correspondingly, it increases the proportion of the population in the productive years of life.

Indeed, very high birth rates speed population growth in two ways: (1) they swell the entering stream of life, and (2) by creating young populations they cut the rate of depletion through death. Today, the lowest crude death rates (i.e. annual deaths per 1000 population uncorrected for age) are not found in the most highly developed countries. The world's lowest crude death rates are found in such places as Taiway, Singapore, Puerto Rico and Chile, where the health protection is good and where a history of high birth rates has left a young population. In the long run, reductions in birth rates reduce growth both directly and indirectly by increasing the average age and, other things being equal, the death rate.

Clearly the possibilities of modernization would be greatly enhanced if rates of growth could be cut in 15 years from, say, three per cent to one per cent by reductions in birth rates. This would mean that populations now growing at rates that double their size in 23 years would come to a rate that would give them 69 years in which to absorb the increase. It would mean that the burden of natural increase in the newly developing countries would then be about that experienced by the United States last year.

One of the most important aspects of the population problem is the attitude of people toward a preferred family size. Although it is true that most societies and individuals desire to limit the size of families, they are usually not in favor of a family size corresponding to zero growth of the population. Efforts of family planning have fallen short of accomplishing the fundamental goal of changing the attitudes of people from a desire for overall increase in population to a recognition that in the end the mean family size has to be limited to a replacement value.

Apart from influencing the motives of people in regard to family size, nothing can do more to help obtain reductions of fertility than the development of more efficient, cheap, safe and acceptable methods of contraception. It is often pointed out that people will use even the best of methods only when they want to have fewer children and much is often made of the fact that in the developing countries people place a high value on large numbers of children. It is also true that strongly motivated couples will utilize inadequate methods of birth control and crude abortions, and that weakly motivated populations need the best possible methods. Today, the situation is much more nearly ready for the widespread practice of contraception than is commonly supposed. More than half of the population of the newly developing nations live under governments that have decided as a matter of national policy to foster the spread of family planning. The list includes most of the countries of Asia, and a goodly number in Africa and Latin America. Most of these countries are developing educational programs to interest and inform their people, and service programs to give them supplies. Careful surveys of attitudes toward reproduction have been made in some 20 countries. They have shown that virtually everywhere the majority of women want to limit their childbearing. This does not mean that they want only two or three children. But it does mean that they want to stop before their families get truly large. Moreover, where services and supplies are made available women are coming seeking them in large numbers. Taiwan, South Korea, Hong Kong and Singapore have clearly reduced their birth rates through their family planning programs. In short, there is the appropriate governmental policy, the demonstrated interest, and the beginnings of actual success in reducing birth rates. Nothing in the biological field would help speed the process more than the development of better methods of contraception. Nevertheless, it must be stressed that further changes in attitudes to family limitation are still greatly needed. It is not sufficient to help couples plan for limited family size as long as the size desired remains much above that needed for checking population growth.

Today, in the developed nations, contraception has changed rapidly from the conventional methods to the combination steroid pill. In the under-developed countries, the new contraceptors are mainly using the modern plastic intrauterine device (IUD). Neither method is perfect, but both methods, are spectacularly effective and successful when compared with the conventional contraceptives.

It has been the intrauterine device that has given the encouragement to governments of underdeveloped nations to build the organizations they require to spread family planning practices. Because those organizations are being built, the next technological innovation can be introduced much more rapidly. It is because they have effective methods, hope for better ones, and have the organizations to make use of them, that such countries as South Korea, Taiwan, India and Pakistan begin to talk about cutting their birth rates in half in 15 years. If they could do so, their long-run problems of modernization and economic development would be greatly simplified.

The world needs better methods than are now available. Clearly the pill and the intrauterine device represent major innovations because they separate contraception from coitus, and both are safe and effective. The intrauterine device is probably at a very early stage of development. We know that there are too many patients who spontaneously eject it, who bleed and have discomfort. On the other hand, apparently the majority of those who accept it wear it without awareness and with very high effectiveness. It now seems that two to three years after acceptance 50 per cent or more of women are continuing to wear their devices. It is likely that better procedures, better materials, and better shapes will lead to a greatly improved experience. Investigation must also seek to solve the riddle of the intrauterine's mode of action and to ameliorate its occasional side effects.

Similar work is needed on the steroid pills to reduce their side effects, to minimize their effects on lactation, to reduce their costs and, perhaps most important of all, to find out systematically and in sustained fashion the actual experience of those who take them.

Work is going forward in a number of places with doses of progestins so small that they seem to limit their effect to the uterine level. Similarly, much work is needed to find means of replacing the oral route of administration with a depot injection, i.e. an injection allowing a steadier rate of absorption and hence, possibly lighter and longer-lasting doses. It would be highly desirable, of course, to have a method that is permanent until positive measures are taken to counteract the contraceptive. Children are often conceived as a consequence of careless contraceptive practice. Doubtless birth rates could drop faster if there were a method in which carelessness meant failure to counteract a contraceptive. Clearly, however, such developments could pose serious problems of personal freedom unless the counteracting agent were freely available.

Only a beginning has been made in basic research. Among other things, we need to know a great deal more about tubal events, including gamete transport, fertilization and zygote physiology. The fields of neuro-endocrinology, immunological suppression of reproduction, blastocyst nidation, gonadotropin chemistry and mechanisms of hormone action urgently need development. A crash program of basic research might produce very important results. The fundamental knowledge, the techniques, and the requisite base of professional skill for such an effort are now beginning to appear.

Perhaps a word about the merits of basic as compared to applied research is relevant. In the long run, of course, all practical results depend on basic research. But in the long run populations will take on multiples of what they are now unless death rates rise. Indeed, unless birth rates drop immediately and substantially the world's population may well increase by more than 50 per cent in the next 15 years. In the past decade it has been the applied work based on many years of preceding basic research that made possible the contraceptive pills, the intrauterine devices and consequently the beginnings of a birth rate decline in some of the newly developing areas. It seems likely that the intensification of applied work holds the greatest possibility of yielding practical results in the next few years. Basic research continues to be greatly needed in order to prepare for new advances in areas already worked upon and perhaps for completely new approaches in population control. In addition, however, the intensification and enlargement of practical work is an urgent necessity. This expansion of practical work should not occur at the cost of efforts in basic research. However, on the problem of population control which confronts mankind now, time is an important dimension which must be met by greatly intensified applied studies.

Basic research is greatly needed in another aspect of population control, the problems of the possible long term effects of various contraceptive techniques. To some extent this can be explored by epidemiological methods analogous to the studies of the relation between smoking and cancer. Such epidemological work should be complemented by research which hopefully would result in predicting effects through thorough knowledge of the full physiology of operation of contraceptives.

Man and His Environment

For thousands of years past man has changed his general environment. Deforestation and primitive methods of agriculture have denuded whole areas and exposed their soil to erosion. Excessive hunting of animals for food and of the large predatory animals in self-defense has wiped out many species either wholly or in many regions. Recently the rise in population density and the developments of modern industry have led to pollution of air, water and soil. In addition, deliberate large-scale use of pesticides has started a chain in which such substances are accumulated in plant and animal tissues and, if taken in with human food, become deposited in the human body. Similarly, the routine addition of antibiotics to the feed of domestic animals may lead to ingestion of such chemicals by man. The effects of these changes in man's environment are not known.

It may well be that some of the agents to which man is now exposed will cause serious diseases, shortening of the life span, decreased fertility, and deleterious mutational changes in genes. Such possible effects may be numerous and yet difficult to discover. This, however, does not imply that dangers do not exist. It has taken decades to establish the relation between smoking of cigarettes and lung cancer and the same may hold true for the relation between new factors in our environment and new diseases (see Reports on Environmental Health, and on Ecology).

Unlike the effects of acute heavy doses of deleterious substances, which lead to severe immediate illness, pollutants are taken up in small amounts and over long periods. Their effect, therefore, may be delayed for years or even decades. Moreover, different individuals may react differently to the same exposure of a foreign substance. Some may excrete more of it than others and thus unload the body. Some may decompose the agent in their tissues where others may leave it unchanged. Some may be more resistant to its effect. If, as an arbitrary figure, 1 in 1,000 individuals will suffer ill effects from a specific agent, only very large-scale studies of whole population groups will reveal them. Such studies would have to make use of large cohorts of individuals which are followed in their pattern of diseases, fertility and life span over very long periods -- longer than the life span of a single generation of investigators. There is some precedent for such studies in the research on the relation of smoking to lung cancer, but the scale of such studies must be greatly expanded. And it may be remarked that while 1 incident in 1,000 seems a small effect, in a population of 200 million it would signify as many as 200,000 individuals who experience damage.

What has been said for contaminants of the environment applies in different form to substances which are intentionally ingested. Only large-scale epidemiological research will reveal whether the contraceptive pills have or have not long-range effects on their consumers, and whether this is true for the variety of pain killers, sleeping pills and tranquilizers. The Federal record systems, and particularly those of the Veterans Administration and the Department of Defense are already available for epidemiological and veterans follow-up studies. They could be made still more valuable by the availability of record linkages, the system of linking together the many independent records of births, illnesses, deaths, of defense and social security agencies and many others. While this system entails the possibility of intrusion into the privacy of individuals, it should be possible to erect safeguards against misuse. Such safeguards will be effective if a climate of opinion prevails that welcomes the attainment of useful information and at the same time frowns on attempts of authoritarian types toward improper exploitation of linked data. Man's biological future depends on knowledge of his experiences, good and bad, and record linkage is one important means of acquiring such knowledge.

Even more subtle than the effect of specific agents on man may be the effects of the changes in his general living. Urban aggregation has removed many men from natural surroundings. The level of environmental noise caused by industrial procedures and automobile and airplane engines has added a new dimension to sensory exposure. The crowding together of individuals in overpopulated regions has changed greatly the interrelations between people who only a few thousand years ago formed small bands with minor contact with one another. The modern development of the science of animal behavior is beginning to give some insight into the interrelations between genetically founded behavioral attitudes and the effects of training and of the individual's environment on overt behavior. We are prone to think of hostility, crime and other antisocial behavior as conditioned by social circumstances. There is indeed ample evidence for it. We do not know, however, how much of personel unhappiness and social distress is a consequence of man's basic biological nature in conflict with an unnatural social and an unnatural non-human environment. The stereotyped movements of caged polar bears and of other animals in captivity have their analogies in mentally ill patients. These modes of abnormal behavior may only be extreme expressions of maladjustments of the human animal. It may well be that research in behavioral biology will furnish deep insights into man's nature and that application of these insights may lead in the distant future to fundamentally new measures of environmental engineering. These will endeavor to fit the environment to man instead of leaving man unfit for the environments which he created. A minor, yet perhaps important tool for such studies are the variety of non-human primates, apes and monkeys. Every effort should be made to assure their survival as species.

Scientific advancement enabled man to triumph over his environment. With technological skills and machinery we are able to move, change, and control our natural resources for our agriculture, forestry, fisheries, recreation, and urban and industrial development. Civilization depends and will continue to depend upon the renewable resources of the environment -- land (soil), water, air and populations of plants and animals both wild and cultivated. Fortunately, the public is becoming increasingly concerned about the status of these resources and the vital role they play in our survival and general well-being.

Environmental pollution has become of increasing concern as the human population congregates in cities and occupies more of the landscape. The public will be pressing for a greater understanding of the function and interaction (ecology) of biological and physical elements of the environment and to apply this understanding to the management of renewable resources to supply man's food, clothing, and shelter. Future needs will call for more than just the maintenance of these biological essentials of life, because the public is becoming aware of the importance of beauty in its surroundings.

In the future, biologists should work jointly with engineers to design cities of quality and beauty. Structures for dwellings and industry should be surrounded by green lawns and plantings of ornamental trees, shrubs, and flowers. Whether in the city or country, clean air and water will be the desired standard. Through care and planning in the sciences of agriculture and forestry, the landscape of the country will be conserved at the same time taking on a simple charm without billboards and auto grave yards. Certain areas will be preserved forever wild for recreation. Environmental biologists along with other interested scientists shall be leaders in developing a strategy for the wise use of our renewable resources while at the same time attaining an attractive environment. (These topics are treated in detail in the earlier section on renewable resources.) Clearly, however, the attainment of such goals does not depend alone on the technical skills of biologists and other scientists and engineers. Fundamentally, people must have the desire to live in harmonious environments. Without broad social motivation supporting their use, the knowledge and the skills of the specialists will lie fallow.

Selection and the Variability of Man

Even without scientific knowledge of genetics in the past man has been able to create a great variety of genetically different strains of domesticated animals and plants. The main agent of such breeding has been selection of desired types. The wild ancestors of cattle, dogs, chickens, wheat, corn and all other organisms appear rather uniform. Nevertheless special procedures such as close inbreeding have shown that a very great amount of concealed genetic variation is present behind the apparent uniformity. This variation enables man to select for traits which appear desirable to him. It has been such selection which led to the establishment of cattle specialized for milk or for meat production, the astonishing manifoldness of races in dogs, and of the types of chickens high bred for egg laying or for meat yield. Similarly, selection has led to disease resistance, heat tolerance and other physiological states. In plants, strains have been selected which are adapted to many climatic and soil conditions, as well as for yields which surpass by far those attained in the wild state.

In man selection has gone on without conscious direction. The different racial groups of mankind differ from one another in many ways. The significance of most of these differences is unknown or at least only incompletely understood. Why do the average body sizes of different populations vary from the pygmies of Africa to the tall Watusis of the same continent, from the shorter Southern Mediterraneans to the taller Scots? Why are the facial features of the Orientals different from those of the Caucasians? It is possible that some of these differences just happened to arise by the chance sampling of genetic types in the distant past when man lived in very small widely separated groups. It is suspected that many others of these differences were the result of natural selection. Dark pigmentation of the skin is an asset in the tropics where protection of the tissues against too much ultraviolet radiation is necessary. Light pigmentation is an asset in northern regions where enough ultraviolet light must penetrate below the surface to transform ergosterol into vitamin D. Long limbs are advantageous as radiators of heat in desert people while short extremities are useful for conserving body heat in arctic climates. What is useful, natural selection preserves, and what is of negative value it rejects.

While it is obvious that the racial groups of mankind differ from one another in specific ways, there is an inclination to consider each such group as rather uniform in itself. This, however, is far from true. The multitude of differences in facial features, body build, height, and other physical as well as mental traits should long have served to correct the false impression of uniformity within given populations. Moreover the polymorphic nature of any human group -- and that of every other species studied intensely, e.g. cattle, chickens, flies -- has become dramatically clear in recent years. Every human group contains a great variety of genes for alternative blood group properties, proteins, and enzymes and new polymorphisms are constantly added to our knowledge. Thus, in every population there are people belonging to blood group M, others to N and still others to MN. Why should there be a variety of genes determining these properties instead of a single type best fitted to survival and therefore having become fixed by natural selection? What is not only the biological but also the sociological significance of polymorphism? Our inability to answer these questions for most, if not all human polymorphisms is evidence for fundamental gaps in our understanding of the genetics of human populations. There must exist selective forces of such nature as to retain variety of genes rather than eliminate all but one of each kind. How these forces act specifically, so as to enhance survival of one gene under certain genetic or environmental circumstances and to decrease its survival under other circumstances is not known and needs to be established in each individual case. If we do not know how we became polymorphic in the past and how we retain the polymorphism at present we cannot expect to predict the future. We are only beginning to be able to define some of the key problems in the biological future of our species and are still groping our way towards finding the means of their solution.

The complexity of selective forces is likely to make necessary the follow-up from birth to death of exceedingly large cohorts and their analysis will require the use of very powerful computers. The biological insights to be gained will teach us the causes of the great load of biological losses in the form of abortions, stillbirths, prereproductive deaths, deaths before the end of the reproduction period and of reduced fertilities and infertility.

Notwithstanding the complexity of genetic population dynamics man has reached the stage where certain gross interference with natural conditions has become possible. It would not take many generations to breed Caucasians whose average adult body size is four feet or Japanese of 6 feet average height. We could breed for obesity or leanness, blue eyes or black, wavy or wiry hair and any one of the physical attributes in which human beings vary. We could also breed for mental performance: high and low scores in overall intelligence tests, for special properties like spatial or verbal capacities, perhaps even for cooperativeness or disruptive behavior. Most of these traits vary not only genetically but also under the influence of environmental factors, as for example size and weight with food, mental scores with social attitudes and educational opportunities. This, however, does not negate genetic components in the determination of the variety of traits. The "heritability" of a trait which is a measure of the part which genes play in the observed variability of the trait may be large or small. More research in respect to heritability of human traits is needed but it is clear already that selection can be effective even with traits of very low heritability.

If man has reached the stage of being potentially able to select his own genetic constitution he has not yet made use of his power. Selection is a harsh process. To make speedy progress reproduction should be limited primarily to those who possess genotypes for the desired traits. Who will decide what is desirable? How much genotypic and phaenotypic variability would be optimal in the human society? Who would dare to prohibit procreation to a majority of men and women? May we expect changes in attitudes of whole societies so that they would accept the self-control of human evolution at the cost of foregoing the private decisions of most people to propagate themselves in their own children? It would not seem likely that such changes in attitudes will come soon. The future of man, however, will extend over incomprehensibly long times, long enough not only to ponder possibilities but also to explore them in actuality.

In order to overcome some of the objections to all-out self-selection by man, the late geneticist H. J. Muller was an advocate of partial selection for the betterment of mankind. Starting from the practice of using artificial insemination in sheep and cattle, Muller proposed the deep-freeze storage of the sperm of the most distinguished men. Such storage was intended to extend over a long period -- perhaps until decades after the death of the sperm donors -- in order to give perspective to the judgment of their being unusually distinguished. The sperm of those who withstood the test of time would then be made available to married couples. A child produced by insemination with donor sperm would have the wife and the donor as its biological parents while the husband would, like an adoptive parent, exert his influence on the child by his personal attributes. This scheme of procedures has a low genetic efficiency as compared to procedures in animal breeding. Its emotional appeal too is limited. Yet its control over man's genetic future granting its limitations, is accomplished by methods which leave room for free choice. Moreover they are already employed in numerous cases of infertility of a husband without, however using the opportunity to choose unusually distinguished sperm donors.

A much more efficient and a most revolutionary way of selecting for specific human genotypes has been suggested on the basis of experiments with frogs and other amphibians, -- experiments whose original purpose had nothing to do with plans for genetic selection. It is possible to take a frog egg before fertilization, remove its nucleus and instead of fertilizing it with sperm implant the nucleus of a body cell from a frog embryo. Such an egg can develop into a normal frog individual. It has the same genetic constitution as the frog embryo whose body cell provided the transplanted nucleus. If the method of nuclear transplantation with resulting full development should become successful with the nuclei of body cells of adult individuals and if it could be applied to man, a most powerful means of controlling the genetic constitution of future generations would become available. Such a method avoids a great drawback which is inherent in the use of normal eggs and normal sperm in selection experiments. The process of formation of germ cells in the ovaries and testes brings it about that any germ cell of even the most distinguished individual carries no more than one half of his genes but also each given germ cell differs from all others by carrying a different assortment of one half of the thousands or hundred thousands of genes. The use of selected sperm from selected men does not, therefore, provide a means of transmitting their genetic constitution. It increases the probability that certain genes which lead to desired effects will increase in the population but, as already mentioned, the efficiency of the method is low. Moreover, the different genes of an individual do not produce their effects in isolation from one another. A person may be distinguished less by having specific genes and more by having specific combinations of them. These combinations have an overwhelming chance of being broken up in the formation of germ cells. The nuclei of body cells, in contrast to those of germ cells, retain the totality of the person's genes so that a child produced by an enucleated egg which was supplied the nucleus of a body cell would genetically be equivalent to an identical twin of the donor of the body cell. Husbands might wish to have daughters who were identical genetically to their wives. This could be accomplished by using a nucleus from the wife's body tissues. Wives might want to have sons identical to their husbands. Other couples might wish to propagate the genotypes of unrelated persons. Moreover any desired multiple number of such a genetic twin could be produced. It would require the collection of unfertilized eggs from the oviducts of many women, removal of the egg nuclei and replacement by the nuclei of body cells of the chosen man or woman. This would be followed by return of the eggs to the uteri of women who then would undergo a normal pregnancy. In this way one could produce identical copies by the tens, hundreds or thousands of any person judged admirable: Mozarts, Shakespeares, Lincolns and Einsteins.

Technically, it is still a long way from the use of frogs eggs to those of humans, but what can be done in frogs today will hardly not be possible in man tomorrow. The biological problem now is primarily one of skill and development of detailed procedures. The first steps would probably be the extension of the experiments from amphibians to laboratory mammals. Once successful in mice or rabbits there would be practical applications to animal breeding. Prize bulls or cows would be perpetuated by identical "offspring" derived from their body cells. From there the steps toward potential human use would not be difficult technically. If there is a strong wish to make such potentialities a reality, it could probably be accomplished within a few decades. Whether there would be general social acceptance for the practice of such radically new procedures in a foreseeable future is a question for which the sociologist and behavioral scientist will have to provide the answer. In any case it seems not too early to ponder the personal and social implications of success at the biological level.

Controlled Sex Determination

The method of transplantation of nuclei of body cells into enucleated eggs as applied to man would provide a means of determining the sex of "one's" children. The nucleus of the body cell of a male will cause the development of a boy, that of the body cell of a female the development of a girl. Independently of this kind of controlled sex determination methods are bound to be discovered which will enable true parents to have children of specified sex. More than a half a century has passed by now since it is known that a man produces two kinds of sperm cells in about equal numbers. In addition to 22 chromosomes visibly alike in all sperm, the nucleus of one kind possesses a relatively large chromosome, the X chromosome and the nucleus of the other kind, a small chromosome, the Y chromosome. In conception, X sperm is female-determining, Y sperm male-determining. It is obvious that it should become possible to separate the two kinds of sperm either by biological or by purely physical methods such as differential centrifuging or sedimentation. No success, however, has been attained yet in spite of some promising leads. If success comes, insemination with the X or Y fraction of semen will assure control of the sex of the offspring. Application to animal breeding would be of economic importance as in the production of mainly females in dairy cattle. If applied to man, subtle psychological changes in the population might be expected. It is likely that no great deviations from a 1 : 1 sex ratio would result since most parents of more than one child seem to desire children of both sexes. The sequence of sexes in a family may, however, change considerably. Instead of the uncontrolled random sequence of boys and girls, it may well be that the majority of firstborn would be boys and that of second-born girls. Since position in the birth order has an effect on both physical and personality traits of the developing offspring the consequences of the first-borns being all boys and the second-borns all girls, may be reflected in behavorial shifts of the population.

Guarding the Genetic Quality of Man

Concern for the quality of the genetic endowment of man has focussed on two aspects. One of these places emphasis on the genetic load which is represented by clearly abnormal inherited traits. The other stresses the desirability of not simply guarding against frank abnormality but particularly against lowering of averages of endowments within the range of normality for such traits as intelligence and other mental attributes. Even beyond this latter goal measures have been proposed for raising existing averages by increasing the genetic endowment of the population. Measures against the transmission of clearly undesirable traits lie within the sphere of negative or preventive eugenics while measures for increasing the frequency of desirable traits fall within positive or progressive eugenics. Preventive and progressive eugenics are fully compatible with one another although their application offers different problems. It is easier to obtain agreement as to what is regarded as undesirable than what is desirable. Eugenic thinking should be encouraged notwithstanding tragic errors of the past.

Euphenics, the engineering of human development so as to overcome the detrimental expression of abnormal genotypes has led to a relaxation of selection against them. Formerly most phenylketonuric children were unable to reproduce; when treated from birth with suitable diet they will now presumably, marry and have offspring. Thus, instead of the "extinction" of the genes responsible for the disease whenever an affected individual does not transmit them to the next generation, the genes will now have a chance to be preserved. This should lead to an increase in the frequency of these genes in future generations and consequently an increase in phenylketonurics. And what is valid for phenylketonuria is similarly valid for all the other genetic afflictions which can now be neutralized by various treatments. This may be illustrated by pyloric stenosis, an abnormal constriction at the junction of the stomach and intestine. It is a relatively common disease of the new born occuring in about 5 out of 1000 live male births and in 1 out of 1000 live female births. Formerly, many infants died as a result of this condition but 50 years ago an operative procedure was designed which permits survival and normal health. Pyloric stenosis has a genetic basis. It is evident that the death of an affected baby results in the elimination of the responsible genotype from the population. Correspondingly, the survival and later reproduction of a surgically treated child ultimately results in the perpetuation of its genotype. It has been shown indeed that among the offspring of successfully treated persons the frequency of infants with pyloric stenosis is from 10 to 70 times higher than in the general population. These children, after having been operated upon, will again later produce a surplus of their own affected kind.

Thus, in successive generations a continuous increase of the disease must be expected.

In detail the speed of accumulation of unfavorable genes in the population depends on many factors. Generally, it will be a very slow process which for centuries will have no easily recognizable effects. Moreover many a "bad" gene whose effects are overcome euphenically may be said to have lost its "badness", wholly or to a large degree so that its accumulation no longer represents a serious biological load even though it may represent a considerable economic load. In addition such accumulation may be slowed down if genetic counseling leads certain carriers of such genes to reduce the number of children born to them or even to refrain from having children. Such counselling is already effective in many cases. Often it can assure worried persons that their fears of defective offspring are unjustified or at least greatly exaggerated, but at times the predicted likelihood of severely abnormal offspring is high. More knowledge of the inheritance and the variability in expression of the numerous kinds of human defects accumulates yearly and the outlook for improved foundations for counselling is favorable. It should be added that the possibility has been discussed that the great insights of modern molecular biology may make it possible in the future to replace specific undesirable genes in a person's cells by desirable ones brought in from the outside. Many biologists think, however, that the prospects for such genetic surgery are doubtful in the foreseeable future.

Differential Fertility

From time to time serious questions are raised about the long-range biological (and for that matter social) effects of differential fertility on the characteristics of populations. These questions arise because there is generally an inverse relation between fertility[1] and socio-economic status whether measured in terms of occupational status, education, or income, and because there are differences in the fertility of the major races. There are also substantial differences in the fertility of the major religious groups. The maximum fertility is found among Moslems, with Hindus and Buddhists next. Christians as a group have lower fertility, and among Christians in the United States the Catholics have higher fertility than the Protestants as a whole. In worldwide terms, however, Catholics run the gamut of all experience, from very low fertility (for example, in North Italy) to the highest fertility in the world in some parts of Latin America. In general, the Jews have the lowest fertility of any of the world's major religions.

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[1] In this context the word fertility will be employed in its demographic usage indicating the number of offspring produced and not in the sense of the opposite to sterility.

In this summary account, only a few sweeping propositions can be ventured.

1. A great deal is known about the actual differences in the fertility of broad socio-economic, racial and regional groups, but very little is known about the significance of these differences for either the social or the biological heritage. Many discussions of these matters cannot be backed up by sound evidence but recently new beginnings are being made to obtain valid information.

2. In biological terms it is probable that differences in reproductive performances among individuals of varying characteristics within all groups are much more important than differences in the average performance between the highly heterogeneous social groupings for which data are readily available.

3. In the developed world, as birth rates have moved downward from those characterizing the mid-nineteenth century to their present position, there has been a tendency for the inverse relation between socio-economic status and fertility to become first stronger and then to weaken. The small-family pattern has tended to come first in the upper classes and in the urban sectors of the population; and only later to spread throughout the society. As progressively larger numbers of governments in the newly developing countries mount national programs to spread the practice of family planning by means of the new and highly effective methods of contraception, it is likely that the trend in the lower social strata of the populations will follow those of the upper strata more closely.

4. In the white population of the United States the differences narrowed substantially during the postwar rise of the birth rate, which was more pronounced in the urban and upper-class groups than in the rural and lower economic strata. The inverse relation remains, however, partly because of an earlier age at marriage in the lower-class groups. However, it is also clear, and particularly in the poverty groups, that much of the higher fertility of the lower status groups would disappear if contraceptive information and services were made readily available.

5. In the United States, the fertility of Negroes differs from that of the white population mainly as a consequence of their lower educational, economic and social status. When one compares similar educational, income and occupations groups, the differences are greatly reduced and in certain cases even reversed.

From a genetic view point differences in fertility among groups of people are important only when these groups differ in their genetic endowments. From a general point of view only those genetic differences count which bear on the mental, behavioral, and social aspects which are characteristic of man.

There is no doubt that a large part of the variability of mental, behavioral and social traits is accountable by the graded differences in non-genetic factors such as wealth and poverty, intellectual stimulation and its absence, attitudes of encouragement and discouragement. There is an immediate task before mankind in seeing that these non-genetic factors are adjusted so that each individual realizes his genetic potential to the fullest. At the same time, however, when the performance of unchanged genotypes may be improved in this way, intense studies on the exisiting genetic variability may make possible the design of realistic blueprints for the control of man's biological make-up. These plans will take account of a future deeper understanding of that concept the "gene pool", which abstracts the genic content of populations from its actual existence in living individuals. In abstract terms control of the genetic future of man consists of manipulation of the gene pool. In concrete terms such manipulation is accomplished by specified reproductive patterns of individuals. The choice between various future plans must be based on value judgments. In order to use the powers of self-control of his evolution man must be clear about the values toward whose realization he is to strive.

When, in the future, populations do not expand any more, it will be desirable to provide social incentives for the perpetuation of certain genotypes and social discouragement for that of others. At the present time of quantitatively dangerous population growth, social pressures might best be directed to lower reproduction in general without qualitative considerations.

Man's view of himself has undergone many changes. From a unique position in the universe the Kopernican revolution has reduced him to an inhabitant of one of perhaps many planets. From a unique position among organisms the Darwinian revolution has assigned him a place among the millions of other species which evolved from one another. Yet, man has overcome the limitations of his origin. Nature in him has reached beyond the hard regularities of physical phenomena and beyond the realization of organic configurations. Man, the creation of Nature, has transcended her. From a product of circumstances, he has risen to responsibility.

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