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# Human Evolution: The Quest for Meaning

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## I METHODS OF STUDY OF HUMAN EVOLUTION

Attempts to understand our past and to predict our future are as old as mankind itself. Really scientific approaches, however, are relatively recent. For instance, Darwin[1] examined the problem of our origins in 1871 in a largely comparative way, giving emphasis to a process that is now considered to be of relatively minor evolutionary influence: sexual selection. It is important, on the other hand, to emphasize that Darwin postulated his theory of natural selection and extended it to our species without having available as evidence any subhuman fossil through which, using as a basis his theoretical concepts, he could satisfactorily demonstrate the probability of man's relation to other primates. During the time that he lived and worked only fossil remains from *Homo sapiens neanderthalensis* had been discovered and described, and there was high controversy about their nature.

As paleoanthropological and archeological data became available, and studies of primate behavior both in the wild and in captivity increased in number and widened in scope, many theories and suggestions were made about the probable course of our evolution. Concomitantly, a large number of scholars explored the fact that written records are available about past events, with the creation of a new area of investigation: historical demography.

In the biological field large progress was being made both in the characterization of our genetic material and in the processes of data analyses. It was only natural, therefore, that population geneticists would turn their attention to extant groups of humans whose way of living approached as closely as possible those that prevailed during the early phase of human evolution. Computer simulation, on the other hand, provided the means to test specific hypotheses based in the field work.

The spectacular advances which are presently occurring in the area of human reproduction, together with the realization that technological progress is not always necessarily good raised new concerns, not about our past but in relation to the future. Will we be able to direct the course of our evolution and are we prepared for this task?

## II THE LIFE OF PRIMITIVE MAN

We can only guess about the life of our ancestors; many details about it will probably never be completely uncovered or understood. Some generalizations, however, are possible. They were distributed in small, nomadic groups; but despite this mobility, the range of individual movements was of course much more restricted in relation to those of their modern descendants. There was more contact with fewer people. These contacts and the interpersonal relationships were much more influenced by socio-cultural rules than is the case today. They were more vulnerable to environmental changes, and the fertility, morbidity and mortality patterns drastically different from those that prevail in our industrial society.

Let us start by discussing the fertility of these groups. There are clear evidences that they lived under a system of strict fertility control. It would be very difficult to reconcile a life of wanderings in the forest with large family sizes, and the observation of present-day hunter-gathering groups confirms this view. How was this control achieved? Probably different communities resorted to different means. Intercourse taboos after the birth of a child occur in many cultures. To this we must add large periods of physiological sterility, due to changes in what has been called the 'critical weight' necessary for the normal functioning of the female's reproductive system. It seems that the maintenance of a minimum level of stored fat is necessary for the onset and regular functioning of menstrual cycles[2], and it is reasonable to suppose that under primitive conditions lactation and early child care could significantly lower this level, leading to transient states of sterility.

Further reproductive control can be achieved through the use of contraceptives (of which we know very little in these societies), as well as by infanticides. Among the Ayoreo of Bolivia and Paraguay, for instance, about half of the recorded deaths were due to the early killing of infants[3]. To this pattern of moderate fertility we should superimpose one of moderate mortality. The population structure of these groups is such that it is possible that many of our modern illnesses did not exist there. As was clearly presented and documented by Black[4], diseases that infect only man fall into two distinctive groups. Those which persist in a person for a long period are highly endemic, but those which are infectious only in the acute phase die out quickly after introduction. The latter could not perpetuate themselves before the advent of large intermingling populations and did not exert selective pressures on the human genetic constitution until relatively recently.

What were, then, the main causes of a death in these early periods of human evolution? Probably violent killings and starvation due to inability to hunt were important, as well as infectious diseases from agents capable of reproduction in other animals besides man (such as the arboviruses). The fact is that old people are seldom found in hunter-gathering societies, and some provide mechanisms for the suicide of elders[3]. Chronic diseases, therefore, are rare.

Other types of differences between primitive and modern man can be considered. Konner[5], after a careful study of the behavior of infants and juveniles among the !Kung San of northwestern Botswana arrived at some interesting conclusions. Infants are in physical contact with their mothers or other individuals for a very large portion of the time. In addition, they are held vertical during most of their waking period, thus receiving extensive vestibular stimulation, and are challenged by the social and physical environment. Other characteristic aspects are their very intense fear of strangers and their early integration into a multi-age child group. As a result of some of these practices, the !Kung infants are advanced in some aspects of neuromotor and cognitive development, when compared with, say, North American children of the same age. It is clear from comparative studies that some of these behavioral traits have deep roots, as well as adaptive functions, and we may legitimately ask if the changes which occurred with the technological progress may not have lead to mental health problems.

Man is territorial in a number of senses. He has a personal space halo, notions of property in land, a willingness to defend areas of ground, and limits to the range of his daily, yearly and lifetime wanderings. Is the hunter-gatherer territoriality natural or acquired? Quite aside from this question, it should be remembered that spacing mechanisms have important consequences for the long-term adaptation, survival and evolution of human communities[6].

Gross[7] has argued that the availability of animal protein limited the size, density and permanence of settlements of the Indian societies of the Amazon basin, while previous suggestions have focused mainly on agricultural potential. The culture of these persons is of course also important, but it should be viewed in conjunction with the environment, as an interacting system.

## III CULTURAL EVOLUTION

Having as a starting point the problems of ethnic formation and inequalities in the development of the peoples of America, Ribeiro[8] elaborated a new scheme of socio-cultural evolution. The formation of new ethnic entities can be seen as a result of the operation upon different societies of a series of *civilizational processes*. These are set in motion by successive *technological revolutions*, conceived as profound innovations in the capacity to act upon nature or in the use of new sources of energy. They have been proceeding at an increasingly rapid rate, and their power of compulsion and breadth of action have progressively enlarged.

Humanity required about a million years to build, from a hunting-and-gathering tribal condition, the foundations for the Agricultural Revolution, which began in a few groups about 10,000 years ago. This was followed first by the Urban Revolution, which matured originally some 7,000 years ago, and then by the Irrigation Revolution, which was expressed some 2,500 years later with the appearance of the first Regional Civilizations. The Metallurgical Revolution, initiated 1,500 years later, was succeeded after only 1,200 years by the Pastoral Revolution. The lapse between the latter and the Mercantile Revolution was reduced to 700 years, while the next interval, which brought the Industrial Revolution was shortened to 300 years. Finally, the Thermonuclear Revolution, flowering at the present time, has appeared after an even briefer interval.

As a consequence of this accelerating rate of change, two successive generations today differ more in experience and world view than did a hundred successive generations in the past. By this process, man, who won the battle for survival in competition with other species and who developed a culture that allowed the subjugation of nature for human benefit, has terminated by finding himself submerged in a cultural milieu much more oppressive than his physical environment, that in turn is deteriorating inexorably.

Viewed as a whole, this scheme of sociocultural evolution is multilinear, since it allows for varying forms of transition from a tribal to modern society. Through this process the human species, originally small in size and divided into innumerable ethnic groups, has been multiplied demographically and reduced in cultural and linguistic diversity. It is not unreasonable to predict for the future a single (or very few) huge racial, cultural and linguistic complex.

## IV THE ROAD TO CIVILIZATION

This process very definitely had a positive aspect: it progressively freed man from the vagaries of environmental change. But the price is considered by many as excessively high. The terrible epidemics that accompanied the rise of the cities are well known. The rate of population growth was, until recently, never sufficient for replacement. In spite of this, cities have been growing almost all the time, due to the continual influx of immigrants from the rural areas. As was aptly described by Bodmer and Cavalli-Sforza[9] « genes, with the people carrying them, originated in the country and died in the cities ».

A dreadful aspect of many modern cities is the pollution that occurs in their water, air or land[10]. The techniques of water purification that worked well at the beginning of this century are becoming increasingly unsatisfactory. An appalling amount of untreated or inadequately treated urban sewage is discharged into river water along with the wastes from slaughter houses, chemical factories, and metallurgical plants. The purifying process usually does not go beyond filtration and chlorination; while such procedures eliminate the coliform bacteria, they do not render it free of viruses or nematodes, and they leave untouched most chemical pollutants (such as detergents, bleaches, dyes, herbicides and insecticides).

The type of air pollution varies from place to place, and about half is referable to exhausts from internal combustion engines. Carbon monoxide makes up some two-thirds of this outpouring of volatile poisons. Hydrocarbons (especially olefins), nitrous oxides, sulphur derivatives and many other products are also released in huge amounts.

Air pollutants accumulate to form smogs (the simultaneous occurrence of smoke and fog) when thermal inversion interferes with normal vertical air movements. Ordinarily the air is warmer at the ground and colder above. During thermal inversion, in contrast, a layer of warm air forms at higher altitude and traps a layer of cold air at the ground. When this happens the local air pollutants can no longer escape and consequently accumulate under it. The phenomenon can sometimes last for months.

It would be foolish to deny the obvious benefits created by modern medicine. However, the development of medical and pharmaceutical industrial corporations is mainly responsible for a new type of disease: iatrogeny, that is, abnormal states or conditions caused by the physician himself, the medical or paramedical structures. The risks associated with drug prescriptions is generally underestimated[11]. In the United States and the United Kingdom 50 to 80% of the adults absorb each 24 or 36 hours a drug prescribed by a physician. In that first country 3-5% of all admissions to hospitals have as the main cause a bad reaction to a drug. Once in the hospital 18-30% of the patients have such a type of reaction. It has been estimated that they may double the time these persons must stay at the hospital. The evaluation of the immediate effects of drugs is relatively simple; a more difficult task is the establishment of risk factors for mutagenesis. Despite recent progress in surveillance programs, much still needs to be done in this area. Of equal importance is the selection relaxation that is occurring due to the survival and reproduction of genetically defective persons.

It has been estimated[10] that today faulty nutrition is the largest single cause of disease in the world. But there are two quite different causes of malnutrition. In underdeveloped countries the most common cause is a shortage of good quality protein; while in prosperous nations the most prevalent form of malnutrition derives from the very abundance of the meals. Ten to 15% of the world's population suffer from actual hunger and approximately one third from some kind of nutritional deficiency. Why should it be so, 10,000 years after the Agricultural Revolution? Levins[12] asserts that « the most surprising fact about agriculture is that it sometimes feeds people ». He adds that at present food does not flow from well-fed areas to hungry ones, the opposite being true: a net flow from 'developing' to affluent countries. The main effort of agricultural research, according to him, is the production of marketable commodities that could be sold to farmers: insecticides, fertilizers or machines.

## V BIOLOGICAL CONSEQUENCES

What is the main evolutionary factor responsible for the emergence of man and his subsequent development? To some the prompt answer would be natural selection (acting on the existing genetic variation) but other scientists, even considering this factor as important, may give more emphasis to other agents.

Darwin presented a very clear and simple definition of natural selection: « The preservation of favorable individual differences and variations, and the destruction of those which are injurious ». Sexual selection, on the other hand, relates to the advantage that certain individuals have over others of the same sex and the same species, with respect only to reproduction. It would be based, therefore, in the competition among males for the acquisition and maintenance of females for reproductive purposes, as well as in the choice, on the part of the females, of particularly attractive males. As a result of this, there would be the accumulation of genetic factors that would manifest themselves just in one sex, giving rise to a marked sexual dimorphism.

The evidence for sexual selection in humans is scarce. A possible example is steatopygia (the accumulation of fat over the buttocks), a characteristic feature of the San from southern Africa[13]. Sex dimorphism in adult stature differs among ethnic groups. This has been attributed both to genetic factors or to differences in nutrition (if male children responded more adversely to poor nutrition than females the difference between the two sexes would be reduced). An interesting suggestion was made by Valenzuela and coworkers[14] concerning the sexual dimorphism in Chilean populations with different degrees of racial admixture. This latter process was highly asymmetrical in that country, with matings of Spanish men with Araucanian Indian women occurring much more frequently than the opposite. If the sex chromosomes have an influence on adult stature and human growth the interpopulation differences found in sexual dimorphism could be explained by this peculiar marriage structure.

One reason why I believe that sexual selection cannot be a leading evolutionary process among primitive groups is the fact that among Brazilian Indians, for instance, *all* males and females participate in the reproductive process[15]. This does not mean that there are not reproductive differences among individuals. But it is very difficult, here and in other instances, to separate what is due to natural or to sexual selection.

## VI CHANCE OR DESIGN?

It has been suggested that natural selection may not be as important in man as it is in other organisms due to the existence of culture. Molecular studies also raised the question whether, at this level, neutral or near-neutral changes might not have been of prime importance. These two problems have been considered in detail elsewhere[16] and I do not need to reiterate arguments here. Suffice it to say that although the neutral hypothesis of protein evolution has been of important heuristic value, many of its arguments now seem considerable weakened after the test to which they have been submitted. The rules governing molecular evolution do not seem to be much different from those which are responsible for the variability at other levels. This variation is the resultant of a delicate balance between random and deterministic events.

There are a series of factors that may affect the fate of a given allele, besides the mutation rate that introduces it in the population and its adaptive value. The ensemble of these factors is called « population structure »[17]. Some of them can be listed as follows: (*a*) Finite population size; (*b*) Nature of the founding population; (*c*) Sex ratio; (*d*) Migration rates; (*e*) Assortative mating; (*f*) Extent of monogamy or polygamy; (*g*) Offspring distribution; (*h*) Fertility correlations between parents and children. Culture can influence all of these variables, thus introducing a stochastic element that affects allele frequencies. It is obvious, however, that the degree of such an influence will depend on the selection coefficient of the allele considered. If this coefficient is strongly positive or negative, the variant will be lost or fixed independently of all these variables.

The complexity of the process involved, the multiplicity of intervening factors and of biological systems make the task of interpreting population genetics data a very difficult one. When the limits of mathematical analysis are reached, or there is a need to interpret data for which no adequate theoretical models exist, it is possible to resort to computer simulation. There are now a large number of simulation programs designed for the study of population structure, which were developed by researchers in anthropology, demography and human population genetics. Although such models have been used for diverse purposes, certain common characteristics are evident, leading to a remarkable similarity in the programs and basic decision techniques[18].

Up to now, computer simulation in human population genetics has been used for the interpretation of gene frequencies or their variances among populations; or to investigate, within a group, problems such as the effect of overlapping generations on genetic drift, that of lethals on birth intervals, and the consequences of certain types of matings (including here reproductive compensation). As an example of these types of investigations, the work of Mac Cluer *et al.*[19] and Li *et al.*[20] will be mentioned. The first group of authors developed a model based on the demography of the Yanomama Indians of Venezuela and Brazil, whose social organization is typical of many primitive societies. They found that perhaps one third of all marriages in this tribe may involve individuals related as first or second cousins, establishing also other inferences about their mating structure. Li and coworkers[20] improved this simulation program to study the question of the survival of a neutral mutant in a population of this type. Confirming earlier results they found that the mean survival time was much less than it was previously surmised (three generations only). They then revised calculations made with different sets of data to obtain estimates of a standard parameter in population genetics (the effective population size), arriving at widely different numbers. Their conclusion is that great care should be employed in evaluations of this parameter, with clear specification as how it was calculated.

## VII THE FUTURE

The extraordinary progress that is occurring in genetic engineering techniques, together with control over reproductive processes are opening unforeseen perspectives for the future control of our own evolution. The genetic material can now be cleaved at highly specific points and transferred from one species to another. On the other hand, we can now make the fertilization of human eggs 'in vitro' and follow the first divisions of the new embryo, implanting afterwards this cell mass in an appropriately prepared uterus and obtaining a viable infant. Isolated human chromosomes can participate in the ontogenetic process of a widely different species, like the mouse[21]. The formation of artificial human clones is leaving the realm of phantasy to become a tangible reality.

How are we going to use this knowledge? To some[22] the possibility, through these techniques, of introducing a major discontinuity in the human gene pool seems dangerous, with the possible creation of a major mismatch between our social order and our individual capacities.

I hope to have clearly indicated that although we have a clear idea about the basic mechanisms that directed our biological evolution, there is much to be learned about details of this process. The few remnant populations that still live today in much the same way as our ancestors provide a precious opportunity to gain insight about our past, and we should study them before they become too acculturated. This is a matter of urgency, since they are changing at a very fast rate. The progress in empirical knowledge should be matched by the development of better and more realistic theoretical models. Ideally, only after obtaining in this way a better understanding of what factors are responsible for our biological present should we enter the adventurous field of genetic manipulation. But it would be naive to suppose that future events will be guided by such a rational attitude. Scientific data are being produced at a very accelerated rate and we are facing the same problems as those of the sorcerer's apprentice, who did not know what to do with his creations. Let us hope for a happy end.

F. M. S.

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