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# The Transition from Food-Gathering to Food-Production in Evolution and Disease

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Pauling's epochal discovery of an electrophoretically abnormal haemoglobin in patients with sickle-cell anaemia has initiated the Molecular Age in modern medicine. The impact of this and other discoveries in biochemical genetics, which has provided a molecular interpretation of the mechanism of evolution, is rapidly altering concepts in many fields of medicine and research. In this mechanism, according to the contemporary hypothesis of microevolution, the individual proteins which characterize a particular species are a relatively direct manifestation of gene structure, which controls their biosynthesis. And it works through interchange of genetic material and enables the new genotype to adapt to a wider range of ecological "niches" previously denied to its antecedents. These are the tools of evolution, but its modus vivendi must be sought in ever changing environment leading to an alteration in these ecological niches. Thus biologic fitness may be defined as the capacity of an organism to survive in a given environmental niche; and it is not a static phenomenon since it is related to a specific environment, and this is prone to undergo a change.

For some half to one million years, homo sapiens gained his livelihood through simple food-gathering of wild fruits and vegetables and lived either in caves or led a nomadic existence in small bands as hunter, fisherman and food collector. Then suddenly—biologically quite suddenly—about 8 to 10 thousand years ago, which represents roughly about one per cent of man's total existence, the first traces of effective food production in husbandry and agriculture appeared. This event resulted in epoch-making historical changes leading to civilization.

Revolutionary changes in man's environment from prehistory into history and to the present, transforming the long-established ecological niches, surely must have altered the nature of his biologic fitness. In a significant minority this fitness, through their inherited constitution, could be impaired in the new environment, and those individuals less able to adapt to it, would tend to be selected against.

When man changed from food gatherer to food producer as a result of domestication of plants (agriculture) and animals (pastoralism), the consequences of this change in prehistory were epoch making. Historians, anthropologists, ecologists and archaeologists have devoted much attention to the momentous changes which followed the discovery of cultivation, consequences which included the emergence of civilization greatly accelerating the course of man's psychosocial evolution (1). But the impact of these epochal historical changes on man's biologic evolution and the possibility that a partial impairment of biologic fitness, brought about by these changes, could be a hidden cause of some diseases with unknown or obscure civilization, still require study.

Already the recognition that profound ecological changes —which in terms of human history date back to remote antiquity and yet are biologically recent and sudden—may be important in civilization diseases is gradually gaining currency in medical thought and research.

It is proposed in this article to deal with this new comprehension which has recently begun to permeate medical thought and an attempt will be made to show that concepts which are stemming from this awareness offer hopes of providing keys to some outstanding problems of medicine.

According to archaeology, civilization, in contrast to preceding palaeolithic and neolithic cultures, is characterized by the emergence of some form of written symbolic language, urbanization with monumentality of architecture and art, a form of political state and legal system and institutionalised religion. Economically, it is based on agriculture (with cultivation of some form of cereal staple) and mining (2, 3).

Cereal economies, as a rule, initiated a more abundant and assured food supply which has been an important factor in the population increase (4), and more recently in population explosion enhanced by preventive medicine (5).

The increase of population and of its density probably had important genetic consequences by subjecting man to explosive selective agencies of pandemic infectious diseases (bubonic plague, smallpox, cholera etc.) and to more insidious selection by holoendemic malaria.

Furthermore, the population increase would have tended to improve man's total genetic endowment by vastly increasing his reservoir of genes resulting from outbreeding which began during the neolithic period but was greatly enriched by civilization. This is in contrast to inbreeding which predominated among small groups of nomadic hunters of preceding food-gathering cultures.

In the biological history of human beings, the transition from food-gathering to food-production, crucial in the development of civilization, in addition to altering his social environment, has also changed man's physical environment and drastically disturbed his ecological relationship with other living creatures. And the impact of this economic change was bound to have other important repercussions on the biology of man.

Human polymorphism or the continuing co-existence of variant genotypes in a certain but definite proportion in the population, resulting from the presence or deletion of one gene but not maintained by recurring mutations (6), is believed to be among the consequences of outbreeding (7); and surely the "Neolithic Revolution" is crucial in this context.

Indeed, profound environmental and ecological changes, resulting from this new method of gaining subsistence, could possibly account for the emergence of polymorphisms such as the sickle-cell trait—a polymorphism which is probably only transient because it is environmental and depending on the specific ecological relationship between man, the mosquito and malaria.

Basing his hypothesis on the recent archaeological discoveries concerning the transition from food gathering to food production in Africa, Livingstone, F. B. (8) suggests that the pattern of ethnic distribution of the sickle-cell trait is historically determined by the spread of agriculture on that continent. This economic activity has developed at different times in various regions of Africa. Livingstone points out that advancing agriculture brings in its train the destruction or thinning of primeval forest, opening up breeding grounds for the mosquito in the thatched roofs and the refuse of neolithic villages, bringing this vector of malaria into more intimate relationship with man. Thus the altered ecological relations between the vector, parasite and host, depending on the critical values of the population density, led to holoendemic malaria.

The sickle-cell trait is believed to confer some protection against malaria and several mechanisms have been suggested as to how this may be brought about (9). Whatever the mechanism, it is now widely assumed that the prevalence of the sickle-cell trait in upwards 20 per cent of some African populations has resulted from the selective agency of malaria. In molecular biology, this represents a profound alteration in the course of evolution in a significant segment of the world's population, and among food-producers of Africa it probably occurred within the short span of 5,000 years.

Indeed, on the basis of epidemiological data of the sickle-cell trait, Livingstone has shown that its prevalence is considerably less in those regions of Africa where agriculture is of a comparatively recent origin, and he points out that these populations have probably been subjected to the selective agency of malaria for a considerably shorter time. Significantly, the prevalence of the sickle-cell trait is negligible among the nomadic pygmies and bushmen, and other contemporary food-gatherers in Africa.

Not only may transient polymorphism be a sequel to the environmental economic forces which have been reshaping the face of continents since the "Neolithic Revolution", but even true or balanced polymorphism, as exemplified by the various blood groups (of different systems) present in the population, is believed to be a consequence of selective evolutionary pressures. Balanced polymorphism, moreover, is widely held to represent genotypes with differing susceptibility to some common diseases (10)—disorders which, as a rule, do not interfere with their reproductive potential (a crucial aspect of biologic fitness) and hence are not very important in the process of selection.

While this may be so at the present time, entirely different circumstances might have prevailed before preventive medicine became effective in the control of pandemics of infectious diseases, such as bubonic plague, cholera, smallpox, diphtheria etc., often fatal disorders which would have operated as explosive selective agents with the consequent development of true polymorphism (11). These selective agencies, however, could function effectively only during Neolithic and historic times because of concurrently developing favourable conditions of the population density, always critical in the epidemiology of infectious diseases—circumstances which were non-existent among the widely scattered bands of nomadic hunters of preceding food-gathering cultures.

But, in addition to those genetic consequences, the impact of the "Neolithic Revolution" had other important repercussions on the biological history of human beings and probably on their diseases.

Indeed, during the spread of agriculture, which disrupted vegetation and the concomitant extermination of many mammals by man, he could easily have become the prey of many parasites which hitherto probably infested other mammalian hosts—now long extinct (12).

But even some parasitic diseases which affected man in prehistory, are believed by some to have altered their manifestations during Neolithic and historic times.

Traditional concepts in medicine die hard and one of the most difficult acts of all is to liberate oneself from the influence of doctrines having the authority of general acceptance. Such influence, one fears, can be discerned in the refusal to reappraise the historical origins of syphilis, a disease which is generally believed to have been brought to Europe by the returning Columbian expedition. This traditional belief is still being adhered to by many medical historians. For lack of convincing prehistoric specimens of this disease in the Old World, many contemporary American palaeopathologists do not as yet commit themselves concerning the origins of syphilis (13), in spite of a most persuasive hypothesis, which, within recent years, has been advanced by Hudson, E. H. (14).

According to this investigator, yaws, pinta, endemic and venereal syphilis, to which he applies the generic term trepenomatosis, are but the varying manifestations of the same disease caused by the trepenoma pallidum (apparently serologically indistinguishable no matter from which source is derived)—manifestations which, he believes, are historically and geographically determined.

He traces the origin of syphilis not to the Columbian era but to prehistory. Hudson believes that palaeolithic man was afflicted with yaws and when he migrated from humid Central Africa to drier regions of savanna and desert, yaws evolved into endemic syphilis which established itself in the early villages of the Neolithic period and has remained as a reservoir of this infection until today.

He points out that urbanization, with its superior hygiene and by eliminating childhood infections which are important in yaws, brought in its train a gradual transition from non-veneral to veneral transmission. This was greatly facilitated by an increasing sophistication and more prevalent promiscuity (temple and commercial prostitution) of the urban adult population.

He has also indicated that a biological gradient is discernible between various manifestations of the trepenoma, a gradation of symptoms which, in addition to historical factors, is also geographically determined. Rainfall and humidity of the tropics determine the development of skin lesions of yaws which becomes endemic syphilis of the desert and the temperate and colder climates. Migrations and climatic changes can have similar effects and can transform the distribution of lesions; and in many adjoining regions a whole spectrum of manifestations of trepenomatosis, gradually merging into each other, can be encountered.

Backed by brilliant reasoning and providing convincing evidence in his historical approach to trepenomatosis, Hudson demonstrates how evolutionary socio-economic changes, by altering the ecological relationship between the trepenoma and its host, were instrumental in transforming its clinical manifestations which, as he points out, can be understood in historical and epidemiological rather than aetiological terms. Hudson's approach to the ecology of syphilis thus further underlines the possible crucial importance of the "Neolithic Revolution" on disease manifestations in human beings.

Not only the altering pattern of infectious and contagious diseases, resulting from socio-economic changes discussed here, is important, however, as providing and evolutionary challenge to humanity. These changes had other epochal consequences. In the first place, by creating new food (possibly alien substrate to his metaboliism) in the form of cereal staples of wheat, rice and maize (economic bases of three main civilizations, European, Eastern and South Asia and New World respectively), agriculture must have also provided a potent challenge to man's metabolism, a challenge which in a significant minority of cases, probably through enzymatic lack or deficiency, he has failed to meet.

Gluten-induced enteropathy (adult and infant coeliac disease) is a case in point and the present writer has drawn attention to the possible evolutionary and genetic implications of this and possibly of other disorders (15, 16, 17).

But the effects of this new food are not confined to the wheat-eating peoples of ethnically European civilizations. Among cereal consumers of all races, an altered pattern of the protein (hence of amino acid) intake has resulted from increasing dependence on this source for protein, at the expense of proteins derived from animal sources paramount in palaeolithic times. Surely, this biologically abrupt and recent change must have thrown strains on man's metabolism and, as suggested by the present writer, may be a hidden cause or one of the causes of some civilization diseases (18, 19).

The ratio of animal to cereal proteins is to some extent an index of the social and economic status of the individual in the economically developed countries, and it also provides the distinction between the dietary habits in these countries from those which are largely underdeveloped. Here vitamin and protein deficiencies leading to pellagra and kwashiorkor are relatively common and add to the already potent selective forces operating among those populations (11).

The idea of Cleave that the provision of highly refined cereals by agriculture may be a cause of peptic ulceration (20) and the suggestion of Yudkin that the total caloric increase, arising from the enhanced consumption of carbohydrates (related to palatability), leads to coronary disease (21), are evocative and probably important concepts, but peptic ulceration and coronary disease interfere with phenotypic but not biological fitness and hence are not relevant in the evolutionary context of this paper.

Domestication of animals for pastoralism and as pets has probably altered the pattern of many diseases such as hydatids and tetanus, with man entering into a new ecological relationship with the animal herds. In addition, pets might disseminate many infections of childhood (22), some of which could have evolutionary implications.

Although pastoralism by itself does not lead to civilization, it also develops new foods (dairy products), which may be alien to man's metabolism, confronting it with another challenge. Lactase-deficiency syndrome probably provides the best known example of such a challenge, and I have pointed out that the use of milk by the adult is an innovation also dating back to the "Neolithic Revolution", making this infant food available for consumption even after weaning. I suggested that if lactase-deficiency is an inborn error of metabolism, it may also be a factor tending to reduce biologic fitness of populations which have only recently adopted pastoralism, making milk an item of the adult diet (23).

Biologically, man appears to have altered little, if at all, since he emerged as a distinct species. However, since late palaeolithic times, roughly 10,000 years ago, his environment has been subjected to drastic changes. It is a biological axiom that the more rapid the change, the less adequate and complete the adaptation. Man's adaptation to this rapid change has been almost entirely cultural (24), his biochemical make-up probably remaining relatively unaltered. It is submitted here that some civilization diseases may in part by manifestations of this maladaptation to a rapidly changing environment and it is hoped that in an evolutionary approach to these diseases, it may be possible to discern clues helpful in the resolution of their causes.

## Summary

### The Transition from Food-Gathering to Food-Production in Evolution and Disease

The transition from food-gathering to food-production in addition to altering man's social environment, has also changed man's physical environment and drastically disturbed his ecological relationship with other living creatures. And the impact of this economic change was bound to have other important repercussions on the biology of man. The increase of the population density produced by an assured food supply had the effect of subjecting man to explosive selective agencies of infectious diseases such as cholera, plague etc. and to a more insidious selection by holoendemic malaria. Human polymorphisms of blood-group systems and haemoglobin variants occurred.
The sickle-cell anaemia as well as syphilis and yaws can be interpreted in historical terms provided by the archaeology of Africa.
The author suggests that agriculture and husbandry by creating biologically new foods in the form of cereal staples and dairy products initiated a challenge to man's metabolism (gluten-induced enteropathy and various disaccharidase deficiencies, that the ability to meet this challenge (an aspect of biologic fitness) is genetically determined and further that this new comprehension of the epochal changes in man's biological evolution brought about by the transition from food-gathering to agriculture and husbandry offers hopes of providing keys to some outstanding problems of medicine.



## Zusammenfassung

### Übergang vom Nahrungssammeln zur Nahrungsproduktion in Beziehung zur Menschheitsentwicklung und zu Krankheiten

Der Übergang vom Sammeln zur Erzeugung der Nahrung hat die soziale wie auch die physikalische Umgebung des Menschen geändert und seine ökologische Verwandtschaft mit anderen Lebewesen tiefgehend gestört. Der Einfluß dieser wirtschaftlichen Veränderung dehnte sich auf die Biologie des Menschen aus. Der Erhöhung der Populationsdichte, ausgelöst durch ein gesichertes Nahrungsangebot, folgte die Ausbreitung ansteckender oder holoendemischer Krankheiten (Cholera, Pest, bzw. Malaria). Menschliche Polymorphien der Blutgruppensysteme und Hämoglobinvarianten traten auf. Die Sichelzellenanämie wird ebenso wie die Syphilis und Frambösie in einem geschichtlichen Rahmen, der der Archäologie von Afrika zu entnehmen ist, gedeutet.
Der Verfasser vermutet, daß die Land- und Viehwirtschaft durch die Schaffung biologisch neuer Nahrungsmittel in Form von Getreiden und Milchprodukten sehr große Anforderungen an den menschlichen Stoffwechsel stellten (gluteninduzierte Enteropathie und verschiedene Disaccharidasenmängel), daß die Fähigkeit, dieser Anforderung gerecht zu werden, was als biologische Eignung angesehen wird, genetisch bestimmt wird, und daß dieses neue Verständnis der epochalen Veränderungen in der Menschheitsentwicklung, die durch den Übergang vom Nahrungssammeln zur Land- und Viehwirtschaft zustande gekommen sind, die Schlüssel zu einigen wichtigen Problemen der Medizin in sich trägt.



## Résumé

### Le passage de l'état où la nourriture était cueillie à celui où la nourriture a été produite dans l'évolution de l'homme et des maladies

Le passage de l'état où la nourriture était cueillie à celui où la nourriture a été produite a également changé le milieu physique de l'homme et de plus a énormément renversé ses rapports écologiques avec les autres créatures. Le résultat de cette modification sur le plan économique a causé d'autres répercussions sur le cours biologique de l'humanité. L'augmentation de la densité de population détachée par une nourriture assurée a eu comme conséquence l'assujettissement de l'homme à des éruptions sélectives de maladies infectieuses et holoendémiques (choléra, peste, respectivement paludisme). Les polymorphismes humains du système du groupe sanguin et de variantes hémoglobines apparaissaient. L'hématite falciforme peut être interprétée en termes historiques tels que fournis par l'étude archéologique conduite en Afrique, et la corrélation entre pian et syphilis est exposée a une interprétation analogue.
L'auteur suggère que l'agriculture et l'agronomie en créant biologiquement de nouvelles sortes de nourriture sous la forme de céréales principales et de produits laitiers, aient mis à l'épreuve le métabolisme humain (l'entéropathie causée par gluten et différentes déficiences disaccharides, que l'aptitude d'avoir resisté à ces épreuves, qui est un aspect d'aptitude biologique, est determinée génétiquement et que cette nouvelle compréhension des changements intervenus dans l'évolution biologique de l'homme à travers les âges marquées par le passage de l'état où la nourriture était cueillie à celui où la nourriture a été produite, grâce à l'agronomie et l'agriculture promet de pouvoir trouver la solution à quelques problèmes inédits de médecine.



## References

1 Huxley, J. (1964): Evolution (The Modern Synthesis), Wiley, New York.
2 Braidwood, R. J., Read, C. A. (1960): Prehistoric Investigations in Iraq, Kurdistan, University of Chicago Press, P. 163.
3 Hawkes, J., Woolley, L. (1964): Prehistory and the Beginning of Civilization, Allen and Unwin, London.
4 Cipolla, C. (1962): The Economic History of World Populations, Penguin Books, Harmondsworth.
5 Dobzhansky, T. (1962): Mankind Evolving, Yale University Press, New Haven and London.
6 Ford, E. B. (1940): Polymorphism and Taxonomy in the New Systematics, ed. J. S. Huxley, Oxford.
7 Lord Cohen of Birkenhead, (1963): Human Constitution and Disease in The Scientific Basis of Medicine, Annual Reviews, The Athlone Press, London, p. 1.
8 Livingstone, F. B. (1962): Anthropological Implications of the Sickle-Cell Gene Distribution in West Africa, in Culture and the Evolution of Man. Ed. M. F. Ashley Montagu, Oxford University Press, New York, p. 271.
9 Allison, A. C. (1965): Population in Genetics of Abnormal Haemoglobins and Glucose-6-Phosphate Dehydrogenase Deficiency, in Abnormal Haemoglobins in Africa, Ed. J. H. P. Jonxis, Blackwell, Oxford.
10 McConnell, R. B. (1963): Amer. J. Med. 34, 692.
11 Motulsky, A. G. (1960): Human Biology, 32, 28.
12 Heisch, R. B. (1956): Brit. med. J. 1, 669.
13 Temkin, O. (1966): The Development and Present Condition of Human Palaeopathology in the United States, in Human Palaeopathology, Ed. by S. Jarcho, Yale University Press, New Haven and London, p. 30.
14 Hudson, E. H. (1965): Trepenomatosis and Man's Social Evolution. American Anthropologist, 67, 885.
15 Shatin, R. (1963): Lancet, 1, 499.
16 Shatin, R. (1964): Scientific Australian, 1, 34.
17 Shatin, R. (1964): Rheumatism, 20, 93.
18 Shatin, R (1964): Neurology (Minneap.) 14, 338.
19 Shatin, R. (1966): Gluten, the Small Intestine and Rheumatoid Arthritis, Presented to the Victorian Branch of the Australian Medical Association, May 5th, 1965. Rheumatism, 22, 48.
20 Cleave, T. L. (1962): Peptic Ulcer, John Wright, Bristol.
21 Yudkin, J. (1963): Lancet, 1, 1335.
22 Webb, C. H. (1965): Pediatrics 36, 521.
23 Shatin, R. (1966): Lancet, 2, 498.
24 Ashley Montagu, M. F. (1962): Introduction in Culture and the Evolution of Man. Oxford University Press, New York.



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