The Nature of Man's Structural Imperfections.[1]

By Sir ARTHUR KEITH, F.R.S.

I.

BETWEEN the activities of Archdeacon Paley and those of Élie Metchnikoff lies the greater part of the nineteenth century. At the beginning of that century we find the Archdeacon extolling the perfections of the human body—just as Celsus had done sixteen centuries before him.[2] By the close of the nineteenth century the alert and fearless brain of Élie Metchnikoff had discovered, or believed it had discovered, that the human body was blemished by many imperfections. The evangelist of this new and startling doctrine approached the study of man's body by an untrodden pathway, one made possible by the advancing science of his day. On his arrival at the Institut Pasteur in 1888, being then forty-three years of age, he set himself to investigate the means by which the human body combats and keeps at bay the swarming hosts of micro-organisms which find a natural habitat in its internal passages and recesses. He saw man's body as a battlefield—the scene of a perpetual warfare—and as his investigations proceeded, the conviction grew on him that the chances of the body's success were imperilled by a heritage of structures which had become out-of-date and useless. In the Wilde Lecture given before the Literary and Philosophical Society of Manchester, on April 22, 1901, he declared that man "was being killed by his intestinal flora," and that his great intestine had not only become useless but was also a positive and continual menace to the rest of his body. He believed that the stomach itself, and also part of the small intestine, could be dispensed with. Early in 1903 appeared "Études sur la nature humaine,"[3] in which Metchnikoff greatly extended the list of man's structural imperfections.

Between the times of Paley and of Metchnikoff lie three great discoveries, and we must take note of them if we are to understand how it was possible for one to praise the perfection of man's structure at the beginning of the nineteenth century and the other to condemn its imperfections at the end. There was first the discovery that man's body was an aggregate or society of living microscopical units; it was Metchnikoff's fortune to approach the study of man's highly complex body through the simpler societies represented by the bodies of the lower invertebrates; it was thus he came by his discovery that certain units of such societies retain their freedom, thus permitting them to serve as scavengers or phagocytes. In the second place, there was Darwin's discovery; Metchnikoff was a convinced evolutionist. He therefore presumed that the alimentary outfit which served in an anthropoid phase of human evolution must be ill-adapted to deal with the dietary of civilised man. There was in the third place Pasteur's discovery, and so far as Metchnikoff's outlook was concerned, this was the most potent of the three. It was under the influence of Pasteur's discoveries that Metchnikoff came to think that the destiny of man lay in the issue of the everlasting contest which went on between the living tissues of his body and the invading hosts of micro-organisms which threatened them. It is noteworthy that of the three men—Darwin, Pasteur, and Metchnikoff—who revolutionised in the 19th century our conception of man's body, and of the struggles to which it is subjected, not one of them was a professed anatomist; the anatomist stood too near to the subject of his study to see it in its true perspective.

Twenty-two years have come and gone since Metchnikoff's studies on "La nature humaine"[4] first appeared, and I propose in this lecture to ascertain how far his doctrines of man's structural imperfections and functional disharmonies have stood the test of time. His thesis presumed that Darwin's theory of man's origin was true; that presumption has been supported by every discovery of the present century, and such evidence as we now have justifies us in believing that the rate of man's evolution has been more rapid than has hitherto been supposed.[5] We realise to-day, more precisely than was possible when Metchnikoff wrote, that the most critical chapter in man's long history opened with the discovery of agriculture, a discovery of but yesterday if we reckon time on a geological scale. Agriculture revolutionised the conditions of human life; it made modern civilisation possible. We have reason to believe that this revolution in the condition of man's life was initiated either in Mesopotamia, Egypt, or adjacent lands not more than 8000 years ago. It is certainly not more than 5000 years ago since agriculture began to be practised in Western Europe. The vast majority of the people of the British Isles, probably 90 per cent. of them, are the descendants of men and women who, 200 generations ago, were dependent on the natural but precarious harvest which is provided by shore, river, forest, and moorland. City life is a new experiment for Europeans; most of us who live in London, if we could go back twenty generations, would find an ancestry which was living on the soil and of the soil; and now the poorest of us can add to our dietary produce brought from the ends of the earth. The alimentary system which was evolved to meet the needs of our primitive ancestors has now to accommodate itself to a modern dietary.

Beyond a doubt civilisation is submitting the human body to a vast and critical experiment. It is not only the alimentary system which is being subjected to new conditions; the bony and muscular framework of our bodies are also being subjected to novel stresses. Of the present manhood of Britain, half earns its bread by muscular labour; the other half lives sedentary lives. Our forefathers when they arrived in Western Europe were hunters; their bodies were unaccustomed to either manual labour or an indoor life; under the

[1] The Lloyd Roberts Lecture delivered to the Royal Society of Medicine on November 16.

[2] See "Evolution of Anatomy," by Dr. Charles Singer (1925), p. 50.

[3] An English translation, edited by Dr. P. Chalmers Mitchell, was published in 1904 under the title "The Nature of Man" (Heinemann).

[4] In 1907 Metchnikoff published a further work, of which an English translation appeared in the same year, edited by Dr. P. Chalmers Mitchell, under the title "The Prolongation of Life." In this Metchnikoff replied to his critics and produced more evidence in support of his thesis. Sir W. Arbuthnot Lane formed the opinion that the great intestine was a useless and dangerous structure independently of Metchnikoff; so also did Prof. Barclay Smith (see an article on the nature of the caecum and appendix by the present lecturer in the *Brit. Med. Journ.* 1912, vol. 2, p. 1599).

[5] See "The Adaptational Machinery concerned in the Evolution of Man's Body," NATURE (Special Supplement), August 18, 1923, p. 257; and "Concerning the Rate of Man's Evolution," NATURE, August 29, p. 317.

stress of civilisation the hunter's body has to serve modern needs. It says much for the adaptability of the human body that it stands these stresses so well as it does. Dr. J. D. Comrie,[6] on examining 10,000 recruits for the army, found that 363 of them suffered from hernia and 113 from flat foot. Such breakdowns in the supporting system of the body do not occur with this frequency among hunting peoples. Civilisation has laid bare some of the weak points in the human body, but the conditions which have provoked them are not of Nature's ordaining but of man's choosing.

If modern civilisation is making new demands on our bones, muscles, and nerve controls, it is otherwise with another important system of our bodies. As our manner of living increases in comfort, the calls on our heat-regulating mechanism become fewer in number and less urgent in character. Our primitive forefathers lived in the open; their bodies, unhoused and scantily clad, were exposed to sun, rain, wind, and storm. Such a mode of life throws an increasing burden on the machinery which regulates body temperature—on skin, on respiratory mucous membrane, and on that elaborate system of reflexes which control the rate of internal combustion. Modern civilisation, so far as temperature is concerned, tends to make the human body a hot-house plant.

Metchnikoff perceived that civilisation had plunged man's body into a new environment, and that the rate of its progress had far outstripped the power of adaptional response which had carried man so far beyond the anthropoid stage. A belief grew within him—almost a grudge—that Nature was letting man down. He brought against the evolutionary powers which preside over the destiny of man both sins of omission and sins of commission. We shall deal with a sample of each. The first complaint on his list of omissions is that we have not shed from our skins the last remnants of an anthropoid pelage; hair on the body, he held, was useless and a source of disease. Whether or not a completely hairless body is desirable we may leave as a moot point; a hairless breed of dogs has been produced and no doubt a hairless race of man could be evolved. In this matter the Caucasian has been outstripped by the Negro and by the Mongol, the most hairless of races. It is more to the point to inquire how man has come by a comparatively hairless skin, and in the solution of this problem we have been making some advance. A hairless condition became possible with the evolution of the higher vertebrates; a fœtus in the womb draws its heat from the mother's body; it has no need of a hairy covering until the period of birth arrives. There is in the Museum of the Royal College of Surgeons of England a chimpanzee fœtus in the eighth month of development; the hair of its head and body has reached a stage identical with that of a newly-born child. A stage of development which is evanescent in the fœtal anthropoid has become permanent in us. We have come by a new character through the inheritance of one evolved in fœtal life. Many of our structural features have come to us in this way.[7] The base of the human skull is greatly flexed. In the fœtal stage of all mammals the basicranial axis is bent, but in man only has this character been carried into adult years. Fœtal inheritance becomes more and more possible for man because civilisation tends to make man's world into a protective womb.

As an example of a sin of commission, the introduction of a new and useless structure to the human body, Metchnikoff cites the case of the hymen. It is scarcely true to describe, as he does, the hymen as a new structure; it is present at a certain stage in the embryonic life of every higher mammal; it is only in the human species that it persists and forms a definite and substantial structure in the fully formed body. The hymen provides another example of the human body coming by a new character by retaining and modifying a structure which made its first appearance during embryonic or fœtal life. When we seek to explain its use we must enter the purlieus of psychology, for round man's sense of sex has grown up a strange hinterland in his subconscious mind. Metchnikoff described the hymen as "an unpleasant impediment," but love, as the world has long recognised, thrives on impediments. The human prepuce, although not a new structure, was, in Metchnikoff's opinion, a useless and dangerous one; circumcision in one generation does not diminish the completeness of its development in the next. In this the prepuce resembles the hymen. Indeed, Metchnikoff said of the latter structure that the only purpose it had ever served was "the overthrow of the dogma of the inheritance-acquired characters."

The examples which I have cited above of the failure of man's body to adapt itself to present requirements are of little more than academic interest, but when Metchnikoff applied his analytical genius to the problems of man's alimentary system, he carried us into the realms where thought becomes the guide to action. "It would be no longer rash to say," so he wrote in 1903, "that not only the rudimentary appendix and the caecum, but the whole of the human large intestine are superfluous and that their removal would be attended with happy results." Since Metchnikoff penned this sentence, the operation of complete colectomy has been performed on many thousands of men and women, but I do not think that even the surgeons who have performed this operation most frequently and most successfully would maintain that a man or woman who has been rendered colonless enjoys that moderate share of health which falls to the average intact individual. If a finger becomes permanently fixed in an awkward position, the hand is improved by the amputation of the offending digit, but the relief thus gained does not restore the hand to its original capacity. The relief afforded by colectomy is of the same kind; the results of that operation in no wise bear out Metchnikoff's doctrine that the colon has become a superfluous organ in man's body. On the other hand, we have only to consult the pages of the medical press, to listen to tales which reach our ears daily, to note the ever-growing demand for patent purgatives, to be convinced that there is, as Metchnikoff maintained, a grave disharmony between the functional capacities of our great intestine and the dietary which modern civilisation has compelled us to adopt. The way out of our difficulties is not to call the colon a useless organ,

[6] *Lancet*, 1919, 2, p. 959.
[7] Prof. Louis Bolk, "The Part played by the Endocrine Glands in the Evolution of Man," *Lancet*, 1921, vol. 2, p. 588. See also Keith, "The Evolution of Human Races in the Light of the Hormone Theory," *Johns Hopkins Hospital Bulletin*, 1922, vol. 33, p. 195.

a "sewage pipe," a "cesspool," but to discover its original purpose and ascertain how far we can modify our mode of living to suit its inherited capacity. What that capacity is we have yet to discover, for we have no complete or exact knowledge of the uses of the great intestine in any animal whatsoever. So far as the human organ is concerned, surgery has stepped far in advance of physiology.[8]

Since Metchnikoff first promulgated his belief that the appendix, cæcum, and colon had become superfluous organs in man's body, our knowledge concerning the evolution of these structures, and of certain conditions which regulate their action, has increased. That increase of knowledge rehabilitates the ancient belief that Nature in her evolutionary mood exercises not only a surprising ingenuity but also the strictest economy. The ferments and catalysts elaborated by plants for their own use were made to serve in the animal body as vitamins. How necessary such substances are for the proper working of the great bowel has been shown by the recent researches of McCarrison [9] and of Cramer.[10] It was for the purposes of economy that the great bowel came into existence. In fishes, the earliest vertebrate forms known to us in the living state, potent digestive juices have to be produced at the expense of body tissues; with the evolution of land-living, air-breathing forms, much of this expenditure was saved by the utilisation of bacterial digestion. The great bowel was added to the original intestine for this purpose, the oldest part of this annex being the cæcum and appendix. The great bowel as we know it in fishes is a mere diverticulum from the hinder end of the gut; it takes no part in the digestion of food. Its epithelium forms a glandular structure which has all the appearance of an organ designed for the supply of an internal secretion.[11] That secretion, whatever it may prove to be, is carried to the liver by the inferior mesenteric vein.

In the mucous membrane of the human great bowel, there are embedded in a stratum of reticular tissue—of reticulo-endothelium—some 15 millions of minute test-tube glands—the glands of Lieberkühn. No one who has noted the structure and setting of these glands, and the fine changes which their cells undergo in the course of action, can believe that their sole function is to supply a lubricating fluid for the intestine; they have all the appearance of also supplying an internal secretion, and the evolutionary history of the colon favours such an inference.[12] The reticular stratum of the colon, which Dr. Scott Williamson [13] regards as the most important constituent of its mucous membrane, and in this I agree with him, represents a spleen of considerable size. Indeed, just as the liver and pancreas represent extrusions of highly specialised parts of the intestinal epithelium, the spleen represents a specialisation of the reticulo-endothelium of the alimentary canal; in cyclostomes [14] the spleen is still intra-intestinal. Nor must we forget how greatly the large intestine is linked to the central nervous system—both by afferent and efferent pathways. When we take all these considerations into account, we must conclude that the great bowel of man is not a useless or superfluous organ, but one which we, in our ignorance, are maltreating.

[8] The reader will find a summary of the anatomical evidence relating to the nature of the appendix, caecum, and great bowel by the lecturer in the *British Med. Journ.*, 1912, vol. 2, p. 1599.

[9] Lt.-Col. R. McCarrison, "Faulty Food in Relationship to Gastro-intestinal Disorders," *Lancet*, 1922, vol. 1, p. 207. Other references to Lt.-Col. McCarrison's researches will be found in this paper.

[10] Dr. W. Cramer, *Lancet*, 1921, vol. 2, p. 1202; 1924, vol. 1, p. 636.

[11] Dr. Doris R. Crofts, *Proc. Zool. Soc.*, 1925, Part I., pp. 101, 170.

[12] I have not mentioned the excretory function of the colon. This has been investigated by Dr. Owen T. Williams, see *Brit. Med. Journ.*, 1912, vol. 2, p. 1281.

[13] *British Journal of Surgery*, 1914, vol. 2, p. 306.

[14] J. Mawas, *C.R. Acad. Sci.*, 1922, vol. 174, pp. 889, 1041.

(*To be continued.*)

High Frequency Rays of Cosmic Origin.[1]

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IT was so early as 1903 that the British physicists, Rutherford and McLennan, noticed that the rate of leakage of an electric charge from an electroscope within an air-tight metal chamber could be reduced by enclosing the chamber within a completely encircling metal shield or box with walls a centimetre or more thick. This meant that the loss of charge of the enclosed electroscope was not due to imperfectly insulating supports but must rather be due to some highly penetrating rays, like the gamma rays of radium, which could pass through metal walls as much as a centimetre thick and ionise the gas inside.

In view of this property of passing through relatively thick metal walls in measurable quantity, the radiation thus brought to light was called the "penetrating radiation" of the atmosphere and was at first quite naturally attributed to radioactive materials in the earth. But in 1910 and 1911 it was found that it did not decrease as rapidly with altitude as it should upon this hypothesis. The first significant report upon this point was made by a German physicist, Gockel, who took an enclosed electroscope up in a balloon with him to a height of 13,000 feet and reported that he found the "penetrating radiation" about as large at this altitude as at the earth's surface, despite the fact that Prof. Eve, of McGill University, had calculated that it ought to have fallen to half its surface value in going up 250 feet.

In 1912–14 two other German physicists, Hess and Kohlhörster, repeated these balloon-measurements of Gockel's, the latter going to a height of 9 km., or 5·6 miles, and reported that they found this radiation decreasing a trifle for the first two miles and then increasing until it reached a value at 9 km., according to Kohlhörster's measurements, eight times as great as at the surface.

This seemed to indicate that the penetrating rays came from outside the earth, and were therefore of some sort of cosmic origin. The War put a stop the world over to further studies of this sort, but so soon as we could get the proper instruments built after the War in the newly equipped Norman Bridge Laboratory of Physics, I. S. Bowen and myself went to Kelly Field,

[1] Address delivered before the National Academy of Sciences, Madison, Wis., U.S.A., on November 9.