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Lane Medical Lectures:
Biochemical Studies of
Nutritional Problems

By

J. C. DRUMMOND

Professor of Biochemistry,
University College, University of London

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PREFACE

The Lane Medical Lectures, founded in 1896 by Dr. Levi Cooper Lane, are given biennially on medical subjects. The lecturer is chosen by Stanford University, but the lecturer is usually given a choice of subjects for a course of five lectures. These lectures are open to medical students and to physicians in the community.

The twenty-fourth course of Lane Medical Lectures was delivered by J. C. Drummond, Sc.D., Professor of Biochemistry and Dean of the Faculty of Medical Science at the University of London, London, England, on April 3, 4, 5, 6, and 7, 1933. Dr. Drummond's subjects covered the field of nutrition and its relation to disease. His previous work in the field of biochemistry, particularly his knowledge of vitamins, made him master of this subject.

L. R. CHANDLER, M.D.
Dean

STANFORD MEDICAL SCHOOL
SAN FRANCISCO, CALIFORNIA
July 5, 1934

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BIOCHEMICAL STUDIES OF NUTRITIONAL PROBLEMS

I. THE CHARACTER OF MODERN PROBLEMS OF NUTRITION

I am deeply sensible of the honor which the Faculty of Medicine of Stanford University has conferred on me by an invitation to deliver the twenty-fourth course of Lane Medical Lectures. I must thank you for a liberal interpretation of the wishes of Dr. Levi Cooper Lane, because, as a biochemist without medical training and lacking experience of human nutritional disorders, I cannot hope to present my subject in true perspective. The rapid advances which are being made today in the study of the relation between the composition of the diet and health and well-being are achieved only by full and active co-operation between laboratory workers and clinicians.

That the health of the body can be disordered by improper diet has been recognized for centuries past. May I illustrate this by a quotation from Burton's *Anatomy of Melancholy* (1621):

The first of these is diet, which consists in meat and drink and causes melancholy, as it offends in substance or accidents, that is quantity, quality or the like. And well it may be called a material cause, since that, as Fernelius holds, "it hath such a power in begetting of diseases, and yields the matter and sustenance of them; for neither air, nor perturbations, nor any of those other evident causes take place, or work this effect, except the constitution of the body and preparation of humans do concur; that a man may say this diet is the mother of diseases, let the father be what he will; and from this alone melancholy and frequent other maladies arise."

There are some who hold the view that the World War will in one direction prove to have been beneficial in its effects on humanity by accelerating the disintegration and disappearance of many obsolete structures of our economic, social, and political systems. That is for posterity to determine, for with the memories of the events of that cataclysm so fresh in our minds and with many of the consequent world movements still actively in progress it is almost impossible for the generations which suffered so bitterly to form an impartial judgment.

It cannot be denied that the upheaval of those tragic years drew attention in the most arresting manner to the lamentable condition into which the health of vast numbers of the populations of our civilized communities had fallen. The medical examinations of volunteers and conscripts and the tests of fitness of women for industrial work revealed in England and in other countries a state of affairs which was truly alarming.¹

¹ In 1931 the rejections on medical and physical grounds of men offering themselves for service with H.M. Army were 50.8 per cent (*General Annual Report on the British Army*. H.M. Stationery Office, 1932).

Gradually it was borne home on those who were concerned with the question that defective nutrition was to a large extent responsible for the incapacitating disorders and, for the first time, the extent of malnourishment in the towns of western Europe was widely appreciated. The fundamental truths underlying the aphorism of Brillat-Savarin, "*La destinée des nations dépend de la manière dont elles se nourrissent*,"² were recognized, and great impetus was given to research into the cause, prevention, and treatment of disorders arising from faulty nutrition. Once again civilization has been saved, only just in time, from the consequences of its own follies.

To what are we to ascribe the wide occurrence of disordered health arising from defective nourishment? Obviously in a considerable proportion of cases poverty plays a part, but the briefest of examinations of the facts reveals that the status of the individual is seldom what may be termed a primary factor, except, perhaps, during periods such as that through which we are now passing, when a profound disturbance of the economic system is in progress.

I am inclined myself to think that we must go much deeper than an examination of man's present environment and that we can find the root of the trouble in the complex adaptations which have marked the path of his civilization.

The following paragraph written by Sir William Roberts is often quoted:

The generalised food customs of mankind are not to be viewed as random practices adopted to please the palate or gratify an idle or vicious appetite. These customs must be regarded as the outcome of profound instincts which correspond to certain wants of the human economy. They are the fruit of a colossal experience accumulated by countless millions of men through successive generations.³

If this view were correct it would imply that man has retained the natural instinct in the choice of foods which is shown by most wild animals. There is I submit abundant evidence that he has not and that civilization has weakened this defense, as it has blunted the acuteness of his sense of smell and of hearing.

Animals and, to a less striking extent, primitive peoples present many interesting examples of this protective instinct. One of the first to draw attention to it was Bunge, who described the craving for salt which is characteristic of most vegetarian races and herbivorous animals and traced its biochemical significance in a relation between the sodium and potassium of the diet.⁴

² Brillat-Savarin, *Physiologie du Gout*, Paris, 1834.

³ Sir William Roberts, *Digestion and Diets*, second edition, London, 1897.

⁴ Gustav von Bunge, *Textbook of Physiological and Pathological Chemistry*, translation of second German edition, London, 1890.

In my own experience a most interesting example of the instinct was provided by a group of pigs which formed the subjects of an investigation on rickets in which I was concerned a few years ago. The animals, divided into three groups, were housed in adjacent pens each of which communicated with a small brick-floored yard in which exercise in the open air could be taken. The "control" group were fed on a ration which was adequate for normal nutrition, whilst of the two other groups one was given a ration deficient in lime and the other an inadequate supply of vitamin A.

The behavior of the pigs when allowed out for exercise was most instructive. The well-fed animals usually lay down or contentedly strolled about the yard, but not so the others. Those suffering from a deficiency of lime spent a large part of their time attempting to lick whitewash from the walls or to root out a fragment of cement or mortar from the brickwork, whilst the shortage of vitamin A stimulated the animals of the third group to search for the smallest blade of grass or a chance weed which might be growing in the cracks of the floor.

To enlarge the illustration, I will refer to the widespread disease in ruminants known in South Africa by the name of Stijfziekte. By many other names this ruinous trouble is known in New Zealand, Australia, and North and South America. Some twenty years ago it was variously regarded as an infection or as a disease due to dietary deficiency of one type or another; the very multiplicity of theories being clear proof that the actual cause was unknown. Increasingly, the evidence pointed to a deficiency of phosphates playing a major part in the causation of the disordered health, but equally clearly did it become apparent that this was not the only factor concerned.

In 1920 Theiler and his group of collaborators⁵ presented a clear picture of the origin of the disease. The main group of symptoms was related to the toxin of an organism, *clostridium botulinum*, which was found to infect the carcasses of dead animals in certain areas. Under normal conditions the transmission of the organism to stock rarely occurs, but when the animals are feeding in districts where the phosphate content of the pasture is abnormally low, the instinct to make good the deficiency leads the beasts to gnaw the bones of any carcasses which may be in the vicinity. In such manner they become infected. This remarkable story has been confirmed in every essential by Smith's⁶ valuable studies of "loin-disease" in Texas.

It is a curious fact that the evidence appears to point to the instinct

⁵ *Agricultural Journal, Union of South Africa*, 1920, reprint 13.

⁶ *Texas Experimental Station Reports*, 1924-26.

being aroused in animals most strongly by a restriction of the supply of an essential mineral.

The matter has been studied in the laboratory by several investigators. Osborne and Mendel⁷ satisfied themselves that the rats and mice when given the choice between food mixtures tend to select that which is the more advantageous for their welfare. Kon⁸ made the test more severe by presenting the rats with separate dishes of proteins, carbohydrates, and salts and observing what balance they maintained by their choice. They were not wholly successful, for whereas they consumed a diet which provided ample calories for their requirement, it contained only 6.5 per cent of protein, an amount only half that necessary to maintain a normal rate of growth. It must be admitted, however, that the conditions of this test were unusually severe.

Sometimes in man we can detect definite traces of the survival of a protective instinct, but even in primitive races it is seldom strongly marked except for certain minerals. In East Africa the search for edible earths rich in calcium was frequently a cause of tribal raids and the evidence points to these products being instinctively consumed to make good the lack of lime in the customary diet. In civilized communities the tendency naturally to correct the balance of the constituents of the diet is seldom exhibited except by children, who may provide interesting examples.

An amusing test recently carried out on a number of infants showed that when given the choice of a wide range of foodstuffs they made a selection which was far from complying with their physiological needs.⁹ If, however, one inclines to the view that it is an instinct which leads the schoolboy to rob the orchard or to pull up and devour raw carrots, one is tempted to think that essentially the same stimulus may be responsible for some of the curious cravings experienced by women during pregnancy. Frequently the desire is for more fresh fruit, which may represent a latent instinct for some essential substance—possibly vitamin C—which is aroused by the demands of the foetus. And yet I have met men who have fallen victims to scurvy without ever once experiencing a desire to eat a protective food and, indeed, under conditions where fresh fruits were constantly at hand.

In considering the dietary customs of primitive peoples, which at first sight might be expected to throw valuable light on the matter under dis-

⁷ *Journal of Biological Chemistry*, 1918, **35**: 19; *American Journal of Physiology*, 1921, **58**: 211.

⁸ *Biochemical Journal*, 1931, **25**: 473.

⁹ *American Journal of Diseases of Children*, 1933.

cussion, complications are frequently introduced by a variety of restrictions, of which those arising from poverty and isolation are not as disturbing as those imposed by religious proscriptions or tribal taboos.

There are, however, not a few examples of tribes apparently free and able to choose a well-constituted and balanced diet failing to do so. The similar conclusions drawn by McCay¹⁰ and McCarrison¹¹ from their extensive studies of the native diets in India have recently been supported by an interesting investigation of two tribes living side by side in East Africa.¹² The Masai are a pastoral tribe of good physique who live almost exclusively on meat, milk, and fresh blood. Their neighbors, the Akikuyu, are agriculturalists, and although they maintain herds of goats these are regarded as a form of currency and are rarely used to provide meat or milk. The diet of the men is almost entirely composed of cereals and potatoes, but, it being considered effeminate to eat green vegetables, these enter the diet only of the womenfolk.

The Akikuyu men are weedy and unhealthy; Orr and Gilks quote Tate as stating that of 16,754 men of one district of the Reserve who were called up during 1917 for enrolment in the Carrier Corps no less than 12,767 were rejected on medical grounds. A large proportion of their ill health is believed on good grounds to be caused by faulty nutrition, for

TABLE I
COMPARISON OF PROBABLE AVERAGE DAILY INTAKE (GRAMS) OF
KIKUYU AND MASAI TRIBES

Food Content	Kikuyu ^a		Masai	
	Males	Females	Males	Females
Protein	99	82	300	165
Fat	22	8	160	90
Carbohydrate	390	220	100	245
Calcium	0.28	1.86	2.94	2.03
Phosphorus	3.00	2.19	4.36	3.19
Sodium	0.48	1.56	1.80	0.94

^a Orr and Gilks (*op. cit.*) point out that "These figures do not take into account any incidental consumption of maize, sweet potatoes, banana, or similar food by the Akikuyu. These would increase the caloric value of the diet without materially affecting the amounts and proportions of the protein, fat, and minerals."

their diet is poor in fat, heavily overweighted with carbohydrate, and inadequate as regards calcium and at least two of the vitamins (Table I).

The comparison between the two tribes may be summarized in the

¹⁰ *The Protein Element in Nutrition*, London.

¹¹ *Studies in Deficiency Disease*, Oxford, 1921.

¹² Orr and Gilks, *Medical Research Council Report No. 155*, H.M. Stationery Office, 1931.

statements that the full-grown Masai male is on an average 5 inches taller and 23 pounds heavier than the full-grown Kikuyu male, and, furthermore, his muscular strength in dynamometer tests is nearly half as great again.^{12a} It is, obviously, unsafe to ascribe this disparity between the two races of tribesmen entirely to the dietary differences, but the evidence is very strong indeed that they are mainly responsible. In Table II is given information regarding the defects found in examining the children of the two tribes.

TABLE II
PERCENTAGE INCIDENCE OF DEFECTS IN KIKUYU AND
MASAI CHILDREN

Defect	Kikuyu		Masai	
	Boys	Girls	Boys	Girls
Bone deformities	62.6	43.7	11.7	14.6
Dental caries	13.7	13.1	1.6	3.6
All dental defects.....	40.0	18.8	8.3	7.3
Anemia	47.8	38.9	11.7	8.5
Enlarged tonsils	56.0	53.3	35.0	52.4
Cervical adenitis	52.0	47.6	40.0	59.8

The differences set out in Table II are very striking and lead one to dismiss as of minor importance the factor of heredity and the influence of racial character. Rickets, particularly of the late variety, was common in the Kikuyu children and rare in those of the Masai. It is interesting to note that the incidence of defects which can be ascribed to a large extent to one form or other of malnutrition is lower in the Kikuyu girls than in the boys. This is doubtless related to the fact that the women and girls of the tribe consume a certain amount of green foods which, as has been remarked, are usually ignored by the males.

Here, I think, we have an excellent example, and others might be selected, of a community free to choose a diet from ample natural sources which would render them far less prone to disease, and yet lacking the intuition to do so. Is it surprising that with the march of civilization man has still further suppressed the natural instinct to choose a healthful mixture of foodstuffs which doubtless was once possessed?

It is not an easy matter to form an opinion as to the period at which malnutrition—other than that arising from famine—became widespread

^{12a} In Burton's *Anatomy of Melancholy* (sixth edition, 1651), we read: "The Tartars eat raw meat, and most commonly horse-flesh, drink milk and blood, as the nomads of old. They scoff at our Europeans for eating bread, which they call the tops of weeds, and horse-meat not fit for men; and yet Scaliger accounts them a sound and witty nation, living an hundred years."

in the towns of western Europe and began to threaten human and national welfare. The medical literature prior to the opening of the nineteenth century gives many accounts of disorders which are today recognized as due to faulty diet, but it is seldom informative regarding their prevalence. The contemporary Bills of Mortality are virtually useless in this respect, owing to the unreliability of the information. Hess¹³ has attempted to trace the extent to which rickets was encountered and gives some evidence, admittedly scanty, that it was of fairly common occurrence in Europe in the seventeenth century. The opinion formed by him, mainly from a study of medical literature, is supported by what is known of the rearing of young children in those times and also by not a few contemporary works of art.

I have attempted to obtain information regarding the extent to which bone deformities and defective teeth were prevalent by reference to collections of skulls and bones of known origin. I am greatly indebted to Dr. G. M. Morant of the Galton Laboratories, University College, London, for drawing my attention to the records of the examination of a large collection of skulls of all ages in the vault of St. Leonard's Church, Hythe, Kent, which probably represent the population of that town between 1250 and 1650, A.D. Although this material has been carefully surveyed anthropometrically the records contain only one piece of information regarding the condition of the teeth. This shows that approximately half the complete palates examined, numbering 199, had lost no teeth before death. It must be borne in mind, however, that Hythe was in those days a very small seaport and that from the standpoint of our inquiry the diet of the people, apart from the inclusion of fish, probably corresponded closely with that of the peasants and yeomen of the countryside.

More significance might be attached to the study of collections of skulls and bone which have been obtained in uncovering old burial grounds in London. Such information as I have been able to collect from the examination of a series of London skulls of the seventeenth century confirms the conclusions derived by Sir Frank Colyer¹⁴ from a study of material obtained from a burial ground used in the City of London during the seventeenth and eighteenth centuries. The figures in Table III are taken from his interesting paper.

His study revealed that approximately 10 per cent of all the teeth present were carious, but that of 103 such teeth in the skulls with mandibles attached no less than 50 were present in 4 specimens. This figure

¹³ *Rickets, Osteomalacia, and Tetany*, New York, 1930.

¹⁴ *Dental Record*, 1922, 42: 257. I am indebted to Dr. E. W. Fish and Mrs. Lindsay for drawing my attention to this interesting paper.

shows good correspondence with that of 9.6 per cent recorded by Turner in a study of 40 skulls of the same period.¹⁵ Both are far below those which would be obtained from a survey of modern teeth in England and suggest that the population was probably in this respect well nourished.

TABLE III

DENTAL CONDITION OF SKULLS FROM AN OLD LONDON BURIAL GROUND

Material	Dentures	Total Number of Teeth	Teeth Present	Lost, Post- mortem	Lost, Ante- mortem	Carious Teeth
Skulls and mandibles	Complete	317	232	85	...	6
	Incomplete	886	583	187	116	97
Skulls	Complete	754	426	328	...	22
	Incomplete	1,269	522	406	341	111
Mandibles	Complete	1,608	791	817	...	31
	Incomplete	1,970	795	682	523	78
Total		6,804	3,349	2,475	980	345

It is, however, difficult to form a clear picture of the diet of the mass of the people of those times. The contemporary diarists and writers give us many graphic and often nauseating details of the gargantuan feasts which weighed down the tables of the wealthy, but only rarely are we told how the poor of the cities or the farm laborers fed. Such material as we can collect leads us to form the reasonable opinion that their food was not greatly dissimilar in character to that of many peasant populations of today. It may perhaps be illustrated by the following passage from Stubbs' naïve *Anatomy of Abuses* (1583):

Doo wee not see the poor man that eateth brown bread (whereof some is made of rye, barlie, peason, beans, oates, and such other grosse graines) and drinketh small drink, yea, sometimes water, feedeth upon milk, butter and cheese; (I say) doo wee not see such an one helthfuller, stronger and longer living than the other that fare daintily every day? And how should it be otherwise?¹⁶

I venture to express the opinion that until the rise of the age of industrialization a large proportion of the population of England subsisted on a diet of this character, and that, apart from a certain amount of rickets which, in the light of modern knowledge, is understandable, malnutrition was comparatively rare except as an accompaniment of pestilence, war, or famine.

The origin of the rise in the incidence of defective nourishment which reached such an alarming level a few years ago can without question be

¹⁵ *Royal Dental Hospital Reports*, 1913.

¹⁶ Philip Stubbs, *Anatomy of Abuses*. Printed in London by Richard Jones, 1583.