THE PREPARATION OF VARIOUS FOODSTUFFS (ESPECIALLY WHEAT AND RICE):

ITS EFFECT ON THEIR CONTENT OF ORGANIC
PHOSPHORUS COMPOUNDS AND ITS
RELATION TO DISEASE.

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IN November, 1910, Professor Ross called our attention to certain papers on beri-beri,¹ and suggested that further inquiry might be of value; since that date we have devoted a considerable amount of time to such researches and to consideration of the literature. In the meantime great public attention has been directed to the question of our bread supply, and as this is closely bound up with our subject, we directed attention to the matter in a letter to the BRITISH MEDICAL JOURNAL on May 6th, 1911.

In 1896 Eijkman² discovered that exclusive feeding of fowls on certain diets led to the production of multiple peripheral neuritis, and many observers have extended his results both to other species of animals and to other diets. Special interest attached to these results when Braddon³ called attention to the fact that the incidence of beri-beri was closely connected with the variety of rice used as the staple food by the various Eastern races, and it has been shown that any rice which produced tropical beri-beri would also produce polyneuritis in fowls. Fletcher⁴ and others have proved conclusively that tropical beri-beri depends alone on the use of rice which has been deprived in preparation of the outer layers, including the pericarp, and is independent of infection, etc.

Holst,⁵ investigating the diseases of scurvy and ship beri-beri, which attack the crews of sailing ships, and are of great importance to Scandinavian nations, found that many articles used as food on ships cause neuritic and (or) hæmorrhagic lesions in birds and animals when used as exclusive diets; and he noted that white wheat bread and barley bread, and also preserved meats (if the temperature used for sterilizing rose above 120° C.) led to neuritis.

Schaumann,⁶ as the result of an exhaustive analysis of the work of these and other observers, and of his own far-reaching researches, has conclusively demonstrated that the cause of experimental polyneuritis and of tropical and ship beri-beri is connected with deficiency of organic compounds of phosphorus—though whether the deficiency is of nucleins, lecithins, phosphatides, phytins, or other classes, is as yet undetermined. The minimum phosphorus requirement of an adult man at work is about 2 grams, and it would seem that the higher animals have not been endowed by nature with the power of preparing their own organic compounds of phosphorus from inorganic phosphorus, nor, indeed, are they probably able to form such compounds of one group from those of another. These bodies are of far-reaching importance to the bio-plasm; indeed, are indispensable, and their absence or deficiency in the food supply will lead to serious symptoms, or even to death. In times of plenty the animal organism stores excess of phosphorus to meet times of stress; in times of deficiency there is no class of compound (not even protein) that the animal organism more carefully hoards and requires than its organic phosphorus.⁶

The experimental determination of the exact pathological effect of deficiency in any one of these groups on the animal organism is beset with great difficulty, since the processes for their isolation are imperfectly known, and the matter is further complicated by the changes in their molecular combination which are induced during separation.

Experimental polyneuritis in animals is, however, produced on the one hand by diets of substances such as rice, barley, and white wheat flour in which the outer layers of the grains have been removed by milling, and in which the proportion of phosphorus is very low. On the other hand, it is originated by foodstuffs which have been heated for a time to a temperature of 120° C. (especially in the presence of alkali) by which the organic phosphorus compounds have been partially broken down, and by substances from which the same compounds have been extracted by long exposure to solvent action. It is not

prevented by the addition of protein (egg albumen), carbohydrate, inorganic phosphates, or the synthetic organic phosphates (glycerophosphates, albumen metaphosphate, etc.); its occurrence is prevented by addition to the diet of substances which are rich in organic compounds of phosphorus, such as yeast, testicular extracts, pancreas; peas or beans (especially the katyang-idjo bean), or of the parts of rice and wheat removed in milling (wheat bran, rice meal), which are also rich in phosphorus; the protective power of these substances is absolute, if given in sufficient proportions, and the amount which is required of each per day varies inversely as its phosphorus contents, and can be arrived at by calculating the quantity necessary to contain the amount of phosphorus maintaining equilibrium for the class of animal used (2 grams P for a man, 0.5 gram P for a dog, a day). Moreover, these same substances (yeast, rice meal, etc.) are not only protective when added to diets but have a marked and rapid curative effect on animals reduced to the last extremity by polyneuritis after a period on restricted diet.

Pigeons, rabbits, apes, dogs, cats, goats, guinea-pigs, and rats are among the animals in which polyneuritis has been experimentally produced; the symptoms prior to death are wasting, diarrhoea, loss of appetite and activity, loss of power in the limbs, retraction of the head, cramps and convulsions, loss of reflexes, rapidity and irregularity of the heart, oedema of muscles and other tissues, possibly also sponginess of the gums and hæmorrhages; after death various degrees of nervous degeneration and muscular oedema can be demonstrated; in addition, changes in bones and bone marrow and hæmorrhages are specially likely to be found in guinea-pigs. These latter animals seem to suffer differently from others, and die on almost any form of diet, restricted as to kind; rats are markedly resistant, and may live for a long time in spite of neuritis; young animals are unsuitable, as their store of organic phosphorus is usually large; pigeons and fowls are specially suitable, as the changes are rapid in onset and easily seen.

It may be briefly noted that pigeons die in some three to four weeks on diets of polished rice, white wheat bread, or barley bread; that the daily addition to any of these diets of 1.5 grams of rice meal (P_2O_5 0.057 gram), 5 grams of wheat bran (P_2O_5 0.055 gram), 1 to 2 grams of katyang bean (P_2O_5 0.015 gram), or 1.5 gram of yeast (P_2O_5 0.057 gram) will suffice to prevent the onset of symptoms and to maintain their health and weight. Similar amounts rapidly and completely cure them when reduced to the last extremity. Several months' continued feeding on such insufficient diets, with partial revival at times with protective substances, reduced a goat to a very low state in which revival even on a rich protective diet was slow. It showed, in addition to the usual lesions, degenerative changes in the central nervous system.

Rye bread (even fine), oatmeal, whole rice (paddy), and barley grain do not set up polyneuritis in pigeons.⁴

Ship beri-beri is a disease of the European crews of sailing ships, occurring usually at the end of the voyages. It is specially apt to develop when (1) in addition to lack of fresh provender, the peas and beans have become hard and dry, and are either uneatable or only rendered soft enough to eat by long boiling in soda; and when (2) the pickled meat has lost nearly 50 per cent. of its organic phosphate by the extractive and decomposing action of the pickle lye (or is repulsive to part of the crew from its taste and smell). Under these circumstances the crew rely mainly on bread, biscuit, rice, and dried potatoes—substances with low phosphorus contents. They suffer from neuritis and oedema and rapidly recover on fresh meat or vegetables being added to their diet, and this recovery is markedly accelerated by yeast, katyang bean, or testicular extracts. On landing from the ships the phosphorus excretion is invariably low—on the average less than 50 per cent. of the normal, though it rapidly rises with change of diet.

Tropical beri-beri occurs in certain Eastern races who use as their staple diet rice from which the outer coats and their contained phosphorus compounds have been removed in milling, in asylums or institutions where similar rice is mainly used, and in the coloured firemen of ships who live on a low diet in which such rice again preponderates. It is a chronic disease and relapses are frequent; the patients recover but slowly even on full diets.

It does not occur in races using partly-milled rice, or in institutions where such rice is used. Its occurrence in certain instances has been proved to be large and constant if polished rice were used in the diet, and has been entirely abolished by the substitution of partly-milled rice (so-called "cured rice", vide Fletcher, Fraser,¹ Ellis,² Braddon,³ and others). In these cases the remainder of the diet was unchanged—their caloric value was ample—the protein carbohydrate and fat almost unchanged. The phosphorus content alone was altered, being on cured rice raised from some 2 grams, P_2O_5 to 4.5 grams P_2O_5 per man per day. Equally efficacious in its prevention or cure are additions of sufficient quantities of rice meal, peas or fresh meat—katyang beans, again, seem to possess the greatest favourable influence.⁷

Schaumann has shown that in these cases, again, phosphorus excretion is very much reduced prior to the change of diet or treatment being commenced, and calls attention to the fact that the transmission of beri-beri from mother to nursing is associated with marked diminution of the organic phosphorus of the milk. Indeed, the nursing generally suffers first, as the maternal organism economizes at the expense of the milk when the failure of dietary phosphorus commences. (See, however, Teruuchi.¹²)

Occasionally in races whose dietary phosphorus is sufficient beri-beri is set up sporadically or epidemically by gastro-intestinal disorders; either intestinal bacteria split and use the organic phosphates themselves, or intestinal catarrh prevents its absorption.

The experimental polyneuritis of animals and sailing ship beri-beri appear to be due to an acute severe deficiency of organic phosphorus compounds (apparently nucleins being most important), rapid in its onset, and equally rapid in its disappearance on suitable treatment. Tropical beri-beri, equally due to deficiency of phosphorus, is, however, due to a long deficiency of less degree; with slower onset but more marked organic degenerations, which take longer to recover.

Schaumann finally calls attention to the strong probability that a similar deficiency of some one or more groups of organic compounds of phosphorus in the diet is connected with scurvy, and suggests that similar deficiencies of other groups or combinations of groups may also play a part in the causation of other diseases, such as infantile scurvy, rickets, osteomalacia, pellagra, and certain forms of malnutrition in artificially reared children. Different groups of these compounds play very different parts in the internal metabolism, and have great influence not only on the digestive glands but on the metabolism of proteins and carbohydrates. Deficiency of any one group or any combinations of groups will probably have its own specific effect, and the effects may further vary in accordance with the demands of the human organism at different ages of life. So deficiency of one group (probably nucleins) may be the cause of beri-beri in normal adults; in pregnant women deficiency of the one group may initiate osteomalacia; deficiency of some other group or combination of groups in infants may lead to rickets.

Schaumann emphasizes the speculative nature of these hypotheses, but points out that the careful proof or disproof of such theories is the foundation of the advance of medical sciences, and it seems to us likely that one at least may be proved true in the near future.

We have ourselves confirmed many of the results of these experiments on polyneuritis in animals, and we found, in particular, that the curative effects of yeast in birds with polyneuritis was even more rapid and complete than we had expected.

We do not propose at present to communicate our results at length, but will shortly summarize those dealing with the wheat bread.

Adult pigeons, previously on ample mixed diet, were fed exclusively on good white wheat bread guaranteed from unbleached and unadulterated flour. They ate it readily and greedily, but loss of weight and diarrhoea soon commenced; the other symptoms of polyneuritis followed, and the first bird died on the fifteenth day. The average duration of life was twenty-nine days, and the average loss of weight 26 per cent., and marked degeneration of the branches of the sciatic nerve was found in some, early degeneration in main trunks of wing and leg nerves in others. Some when exhibiting marked lameness or convulsive seizures were revived rapidly and fully by

administration of yeast (allowances of one or two days have been made for these in calculating the day of death).

On wholemeal and standard bread the birds remained perfectly well for seven weeks, and had gained on the average 8 per cent. of their original weight. Some, indeed, paired and laid eggs. One pair (the experiment was abandoned during the sitting) have hatched their young; the others abandoned (and ate) their eggs on the diet being changed to white bread, and began to go downhill.

These results, especially in conjunction with those of Holst (white bread), Schaumann (white meal), and Leonard Hill¹¹ (white and standard bread on young rats), appear fully to bear out the claims put forward for the superiority of wholemeal breads in comparison with white bread.

It is interesting to note that some degree of rickets is almost universal among the children of our poorer classes—so common, indeed, by comparison with Germany that it has earned the name of the "English disease" in the latter country; and it is less common in the Highlands of Scotland and among the Irish peasantry. The diarrhoea, marasmus, listlessness, spasm, convulsions, oedema, and neuritis of the pigeons on white bread correspond closely with the diarrhoea, marasmus, listlessness, tetany, convulsions, oedema, and limb-tenderness of the rickety child.

If we exclude cases among infants who have been entirely reared artificially (sterilized milk is probably to some extent "denatured" by heat), the diets of these children of different races are to some extent similar; most of them get some milk (often poor in quality and insufficient in quantity no doubt) and polished rice, and they also receive as the basis of their food the form of bread used in the country.

The Highland child still usually receives oatmeal containing 0.9 per cent. of P_2O_5 , mainly in organic combination; he does not often suffer from rickets, but sunlight and air may aid in its prevention. The Irish child gets probably fresh milk and butter (1 per cent. P_2O_5) in addition to potatoes, which contain a fair amount of phosphorus near their skins. Light and air here again may play their part in protecting him from rickets.

The German child gets rye bread, and in this grain the organic phosphates are evenly diffused throughout, and even fine rye bread contains sufficient (1 per cent. P_2O_5) of these compounds.⁴ He does not suffer from rickets in the same proportion as the English child, whose diet, perhaps insufficient in caloric value, is apt to be largely composed of skim milk, margarine (P_2O_5 0.03 per cent.) and white bread (P_2O_5 0.2 per cent.), all notably deficient in organic phosphates. Much white bread is now made in wholesale bakeries with baking powder—even yeast-baked bread contains very little yeast. Occasionally he gets some meat, often unsuitable from its nature or cooking, and therefore hurried through the intestines. It seems highly probable that rickets is at least in part due to this deficiency in diet, though, no doubt, infectious enteritis, faulty absorption, lack of air and sun, and other conditions all contribute to swell the total, and it may well be that Schaumann and his co-workers on tropical diseases may have indirectly aided in elucidating the etiology of this disease.

This work and the present agitation for a more natural bread may, then, have a wide-reaching effect in lowering infantile mortality, bettering the physique of the nation and lightening the overcrowding of hospitals. At present we use the phosphates of the wheat and rice as food for our prize cattle.

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THE Cavendish Lecture before the West London Medico-Chirurgical Society will be delivered at the Kensington Town Hall by Professor A. Neisser on June 27th at 8.15 p.m., the subject selected being the evolution of the modern treatment of syphilis.