1925

KENYA

324

28578

OTTISH OFFICE. S.O.
(CAPT W.E.ELLIOT)

DATE
20th June 1925.

REC'D
23 JUN 25

CIRCULATION :—

Mr. Ellis

Mr. Bottomley

Mr. Green

Asst. U.S. of S.

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.....

Perm' U.S. of S.

Parl' U.S. of S.

Secretary of State.

RESEARCH WORK IN CONNECTION WITH PASTURE GRASSES.

Indicates investigation which Dr Orr would be able to carry out. Suggests Director of Agriculture be consulted. States as to cost, and encloses publications on animal nutrition.

Previous Paper

E 27074

MINUTES

? We should now send to Kenya copy of Captain Elliot's letter of May 3rd & Mr Bottomley's reply of 6th June, explaining that in view of Dr Orr's co-operation in the collection of East African grasses, the matter was referred to him in the meantime. Enclose copy of this letter of 20th June with all enclosures, and ask if the O.A.G. will let us know if he agrees to the scheme & if so, if he will arrange for the Deputy Director of Agriculture to send home at once any information bearing on the subject which they may be able to collect.

? Send copies of desp. to Kenya & all (except print) enclosures, to Uganda & T.T. asking them to report by despatch whether they wish to be represented in the

Subsequent Paper

M.O. 34317

S. W. 15 6 28

As regards finance the E. A. Contribution should surely only represent the extra cost of passages involved by D. Off visiting E. A., plus subsistence while in E. A. The figure £1000 12 / would about cover a passage from Southampton round Africa & London, & thereforeAlmost exclusive

As regards the secretary of ~~as~~ going with D. Off to S. Africa in any case, it will obviously be convenient for him also to go to E. A., on the other hand if he would not go out for the S. African visit alone, it [illegible] seems doubtful whether he should go because of the proposed S. African visit.

Before writing to Governors as proposed, could we put these points to Capt. Elliot & ask him to clear them up?

Yours ever

Sir Bottomley

I attended yesterday [illegible] meeting of the Sub Cttee on the Phosphate Content of Natural Pastures.

As regards the general question, the scientists seemed to think that Dr. Orr had hit on a promising line of research. The Sub-Cttee is recommending that he should be released for the S. Africa visit, with possible extension to Kenya; and it will also propose that a memo somewhat on the lines of that attached should be circulated to Dom. & Colonies with a view to collecting any info in the Empire which may bear on the question.

Meanwhile Capt Elliot would like us to get in Kenya for samples of grass if one could get the samples over quickly enough to arrive in time for them to be studied before Dr Orr leaves.

[illegible]

He gave me the attached rough draft of a telegram, & I submit a draft based on it.

When Tel has gone G.D. should see above minute [the minutes of the Sub Cttee will of course be registered later & will show the position more fully]; & we can then want to hear from Capt. Elliot as to Dr Orr's visit to Kenya.

I gather that there will definitely not be time for him to go to Uganda & T.T.

(J) Jeffreys
10/7

C.O. 11/7/25 stamp

connection early ~~start~~ proceed of research
ker
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mineral content of pastures

~~connection with other~~ entire work

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C.R.E.

(C.)1.

COPY NO. 1

COMMITTEE OF CIVIL RESEARCH.

SUB-COMMITTEE ON MINERAL CONTENT OF NATURAL PASTURES.

The following Sub-Committee has been appointed by the Committee of Civil Research to consider the above question, (See Paper C.R.(C)5).

Captain Walter Elliot, M.C., M.P.,
Parliamentary Under Secretary for Health for Scotland. (CHAIRMAN).

Sir Walter M. Fletcher, K.B.E.,
Secretary, Medical Research Council.

Sir Robert Greig, M.C.,
Chairman of the Board of Agriculture for Scotland.

Sir A.D. Hall, K.C.B.,
Chief Scientific Adviser and Director-General of Intelligence Department, Ministry of Agriculture and Fisheries.

Mr. Maurice Headlam, C.B.,
Assistant Secretary, Treasury.

Sir Thomas H. Middleton, K.B.E., C.B.,
Commissioner, Development Commission.

Professor T.B. Wood, C.B.E.,
Professor of Agriculture in the University of Cambridge.

A Representative of the Colonial Office.

A Representative of the India Office.

The First Meeting will be held at 2 Whitehall Gardens, on Thursday, July 9th, at 12 Noon.

(Signed) A.F. HEMMING) Joint Secretaries
" T.H. MACLEAN) to the Sub-Committee.

2, Whitehall Gardens, S.W.1.,

July 6th, 1925.

SECRET.

C.R.(C) 5.

COMMITTEE OF CIVIL RESEARCH.

7

MINERAL CONTENT OF NATURAL PASTURES.

NOTE BY THE SECRETARY.

The attached Memorandum is circulated by the direction of the Chairman. It discusses the pastoral aspect of the problem of mineral requirements of stock, and has a practical bearing on stock-feeding in many parts of the Empire. The subject is attracting much attention in the United States of America because of its economic importance.

Lord Balfour wishes the Committee to consider the desirability of referring the Memorandum (and other relevant papers) to a Sub-Committee.

(Signed) THOMAS JONES.

Secretary to Committee of Civil Research.

2 Whitehall Gardens, S.W.1.
1st July, 1925.

An investigation which has been carried out at the Rowett Institute during the past three years, has shown that the mineral content of uncultivated pasture varies in different localities in Great Brit in, and that the further the mineral matter in the pastures differs in amount and composition from that of cultivated pasture, the less is its feeding value, as determined by the number of stock it can carry, and the health and breeding capacity of the stock. (Reference No.1:- Typed report on investigation on Mineral Content of Pastures by Elliot, Orr and Wood.) X

Recent experimental research in nutrition has produced evidence that deficiency of certain mineral elements in the diets for long periods, leads to malnutrition, which is accompanied by decreased rate of growth in the young, decreased fertility in breeding females, and increased susceptibility to disease. (Reference No.2, pp.21-25 and Reference 3, pp.3-12, reprints of articles by Orr.) X

It is known that there are wide ranges of pasture in different parts of the Empire where malnutrition is prevalent and is responsible for heavy losses in the stock. In a number of these cases, the malnutrition has been correlated with deficiencies of certain mineral elements in the pasture. In a few areas, local investigations

X Not circulated.

have been carried out, and the nature of the deficiency determined. In these [illegible] prevent the malnutrition, either by feeding direct to the animals those minerals which are not supplied in sufficient amount by the pasture, or by altering the composition of the pasture through the application of mineral fertilisers to the soil. Thus, in the Transvaal a type of malnutrition in cattle found to be due to a deficiency of phosphorus in the pasture, is now prevented by feeding bone meal which is rich in phosphorus: in a district in Australia a type of malnutrition characterised by bone lesions and paralysis has been prevented by applying phosphate to the soil: and in certain inland districts in America high mortality in young pigs and lambs has been prevented by feeding iodine. (Reference No.4. pp. 45-46:- Reprint of article by Theiler and Reference No.2, pp.19-22).

In the Falkland Islands, the condition of malnutrition has become so acute during the last few years that it became a matter of urgency to discover and remove the cause. An investigation has shown that the primary cause of the malnutrition appears to be the depletion of the soil in calcium and remedial methods are being suggested. (Reference No.5:- Typed report by Orr to the Governor of the Falkland Islands and Reference No.6, pp.16-19, report by Munro.)

It is known that in addition to these districts named above, there are other districts within the Empire, where there is malnutrition in stock which is probably due to deficiencies of one or more mineral elements in the pasture. Thus in Kenya Colony as the slow growing native sheep and cattle have been improved by the introduction of rams and bulls of the modern rapidly maturing type, mortality has increased in proportion to the degree of improvement of the stocks. (Statement to the writer by Mr.Cole of Kenya Colony).

It is understood that a scheme for milk production on a large scale is being developed in this Colony. Owing

to the requirements of mineral matter for the formation of milk, the dairy cow is more susceptible to mal-nutrition due to deficiency of minerals than any other animal. If the modern type of milk cow, with its great capacity for milk secretion, is put on pastures deficient in one or more of the essential mineral elements, there will be either a very low milk yield or a high mortality. From the results of past experience of similar cases, it might be predicted that both will occur.

In all these cases of mal-nutrition which occur when herbivora of the modern improved type are put on natural pasture, the same fundamental cause is operative. There is deficiency of one or more mineral elements in the pasture. This forms a limiting factor to the rate of growth, and the elaboration of growth material by the mother. The native herbivora have evolved with a rate of growth adapted to this limiting factor. When however, the modern type of animal with its relatively enormous capacity for growth is put on this pasture, growth proceeds at a rate greater than that which the amount of each of the essential constructive elements present in the pasture can support. The resulting mal-nutrition, with high incidence of disease, is of the same nature as that which develops in experimental animals put on ill-balanced rations.

Although the fundamental principle involved appears to be simple, it should be stated that as each case is investigated there appear subsidiary problems which are not simple, and for the solution of which there is required the assistance of research workers in widely different branches of science, and also of men of practical experience in stock-farming and the allied industries. It is believed however, that if full

advantage were taken of the information which has already been obtained in the course of research in animal nutrition and of the practical experience which has been gained in local attempts to prevent malnutrition, it would be possible to devise means for preventing malnutrition occurring in areas where the problem has not yet been thoroughly investigated.

The Rowett Research Institute,
ABERDEEN.

26th June, 1925.

Captain Elliot says he is going
about 8.0 m. towards the
Kaduna frames. They will ask
Kenya to put up £100 out of
£500 (Kenya farmers are
contributing £150) and he wished
to work hand in hand (cancellation if
necessary) on the understanding
~~that he will pass on the~~
that there is a good chance of
Kenya joining.

I agreed to the working, and
I said that while we should
welcome not join any Kenya
we would give a guiding hand
at this stage. He quite saw the
difficulty.

They will write on
lines now to the Kenya

21st June

Dear Billy

I enclose an "Official" answer re the King's stock problem. It has however happened a great deal in the last day or so. I got over from Aberdeen & Jeffy asked us both to dine with A.J.B. Wemyss and Cole Hamilton. We explained the whole thing and he became quite humoristic on the subject and considered it exactly the sort

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20th June, 1925.

My dear Ormsby-Gore

Thank you for your letter of the 6th instant about Dr. Orr's proposed visit to Kenya. I have discussed matters with Dr. Orr and we think that in the course of a short visit it would be possible to ascertain:

(a) Whether there were any signs of malnutrition in the improved breeds of stock imported to the country, or being bred in the country from imported sources.

(b) Whether the signs of malnutrition are in any way of the same nature as those found in other localities, and believed to be due to deficiencies in the pastures.

(c) If thought desirable, to make arrangements for the carrying out of practical feeding tests with stock, to determine whether any supposed deficiencies in the pastures could be improved by the direct feeding of the materials supposed to be deficient.

There is a Department of Agriculture at Nairobi with Chemical and Pathological Laboratories with whose representatives we have been in touch, and if it were thought that an investigation might give results of economic value, it might be possible to arrange for co-operative work with the Agricultural Department at Nairobi, and place at their disposal all the data and other information which has been accumulated by the

The Hon. W.G.A. Ormsby Gore, M.P.

Committee/

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The Hon. W.G.A. Ormsby Gore, M.P.

Committee/

Committee of Elliot, Wood and Orr.

If Uganda and Tanganyika are pastoral countries, they should be visited, provided there are any improved stock in these areas. It might also be possible to visit them on

Before deciding whether anyone should be sent out, it is suggested that Mr. Harrison, Director of the Agricultural Department at Nairobi should be consulted, and if he thinks that the investigation is likely to yield results of value, it would be useful if he could be asked to co-operate and take charge of any work which may be done there. Information about work already done in this country could be sent to him, and perhaps he could be asked to send back any information bearing on the subject, which he thinks might be of value. This would enable a provisional plan to be made out before visiting the country, and so get the maximum amount of work done during the short visit.

With regard to publications, while the subject has been referred to in several publications, copies of some of which are enclosed, the information on the subject which has been accumulated during the last three years has not yet been published, although it is being written up for publication and a series of papers will be appearing in October, November and December.

The real "preparatory work" is the experience of the local stock-breeders who have now had a number of years of ranching in which time, so far as I can gather from discussion with representative men, they have accumulated "clinical" data which it would be most valuable to survey on the spot.

Yours very truly,

Walter Elliot

enclose a Statement of necessary reference suggested) that the Kenya ranchers would put up any towards this.

EXPENSES OF AFRICAN INVESTIGATION.

Ticket from Southampton to Cape Town - Rail - Cape Town to Durban. Durban to Mombasa. Mombasa to London. including rail Mombasa to Nairobi and return.	£174.12.7.
Subsistence 42 days @ 25/- per day.	52.10.0.
Total cost.	£227. 2.7.

If journey continued to Uganda and Tanganyika an additional £50. would be involved.

These are simply subsistence figures and therefore the inclusion of a Scientific Secretary would mean an equal addition - total £454.5.2.

The Influence of Nutrition on the Incidence of Disease.

By J. B. Orr, Rowett Research Institute, Aberdeen.

In the history of Medicine, there has always been a tendency to assume that disease is due to the presence of some noxious substance in the body. The discovery, as a result of the brilliant researches of Pasteur, of the association of certain infectious diseases with the presence of specific micro-organisms afforded what appeared to be a complete justification for this assumption. Hence the efforts of modern medicine have been concentrated almost exclusively on determining causal relationships between pathological phenomena and toxins, produced by bacteria, or evolved through disordered metabolism, or introduced with the food, and in finding means of preventing their occurrence or counteracting their influence.

The methods of preventive medicine are based on this conception of the etiology of disease, and they have been attended with a remarkable degree of success. It is now beginning to be recognised, however, that the absence of substances essential to health is as important as the presence of substances that actively interfere with health. Deficiency of certain substances which are essential to the physiological well being of the body result in the development of pathological phenomena which, in some cases, may be so severe that of themselves, they constitute recognised diseases and in other cases, though not producing such marked stigmata, reduce the power of the animal to resist invasion by pathogenic organisms.

The modern tendency is therefore to study the antecedent deviations from the normal physiological condition, as well as the later and grosser manifestations, on which hitherto, attention has been too exclusively concentrated. The normal condition, in which there is perfect performance of all the physiological functions, is possible only in a state of

perfect nutrition, and that depends upon the food and certain environmental factors, such as sunshine and exercise, which affect the metabolic processes. Dietetics has, therefore, become an important branch of preventive medicine.

The profound influence of the food supply in maintaining that proper and co-ordinated functioning of all the organs of the body which constitutes health, is apparent, when one considers the conditions upon which the maintenance of these functions depends. Though the functions of different tissues are different, yet the sum total of their activities is relatively constant. It follows that the supply of the materials required to maintain the total activities must be of a very definite character. Hence the composition of the body fluids, from which the tissues draw their supplies, must be maintained of constant composition. But, in the metabolic processes which take place within the living cell, there is a continual breaking down of compounds with the production of substances of no further use in the economy, and concurrently with this destruction, there is the building up of compounds from materials which must be supplied to the cell from without.

Provision is made within the body for the prompt elimination from the blood of waste products. But the supply of new material is dependent upon the diet. Though the proportions of the essential constituents of the food in any day's intake may be different from what is required to maintain the proper composition of the blood, the regulating mechanisms of the body are able to make the necessary adjustments, provided the deviation of the balance in any one direction is not too long maintained. The excesses of one day, in many of the essential constituents at least, may be stored and be available to make good the deficiencies of another. When, however, over a prolonged period the diet is of such a nature that there is an absolute deficiency in the amount of one or more of the constituents absorbed from the gut, or such an excess of certain constituents that the assimilation of other constituents is interfered with, then the proper physiological balance in the blood cannot be main-

tained, the functions of the different organs and systems of the body are interfered with, and there results a disordered functioning of the cells which is the ultimate basis of all disease.

The practical importance of supplying in the food a sufficiency of energy-yielding constituents and of proteins has always been recognised, but it has been too readily assumed that a diet which satisfies these requirements will provide the other essential dietary constituents in the amounts and proportions necessary to maintain the physiological balance of the constituents of the body. There is a large accumulation of modern data to prove that absolute or relative deficiencies of food constituents is a common cause of disease in human beings. It is of interest to note that the occurrence of some of these deficiencies and the resulting pathological phenomena have been recognised more fully in the past in veterinary medicine than in human medicine. Indeed some of the recent work done in connection with human dietaries merely confirms results obtained by earlier workers from experiments and observations made on farm animals.

A few examples may be given of diseases which arise as the direct result of dietary deficiencies. Under-nutrition and over-nutrition might perhaps be included under the head of imperfect diet, but their results are so well-known that they need not be discussed here. The examples will be chosen from what have become known as deficiency diseases, i.e., those caused by deficiencies of minerals or of vitamines. In certain cases of these deficiency diseases all the chief symptoms can be attributed directly to specific dietary defects. In other cases the prominent symptoms are those due to bacterial infection, but the predisposing cause of the infection is malnutrition induced by a defective diet.

Dietary Deficiencies as the direct cause of Disease.

The two minerals which are required in greatest amounts by the body are calcium and phosphorus, and, owing to the need for these as constructive material in growth, the animals most liable to suffer from deficiency are growing animals, or those pro-

during food for growing animals, *e.g.*, cows and horses. The danger of a deficiency of calcium in the ration of growing pigs and cattle was noted as early as the middle of last century, and the therapeutic value of the addition of lime salts to the food of calves and young pigs urged by Hutyra and Marek[1]. Recently McCollum and his co-workers[2] have shown that in young animals fed on cereal grains, there is liable to be a deficiency of calcium, with resultant limitation of the rate of growth. In experiments with pigs at the Rowett Institute we have noted that on certain diets of commonly used feeding stuffs which are poor in calcium, there develops "pasmophilia, and frequently gastro-intestinal disorders. The animal becomes lethargic and the coat gets rough and staring.

Elliot Orr and Crichton[3] have shown that calcium deficiency may be the cause of rickets in pigs. Hess, Unger and Pappenheimer[4] have shown that deficiency of phosphorus may also lead to rickets. With regard to this disease, it seems that the deposition of calcium phosphate in bone depends upon the presence of calcium and phosphorus in the blood in the proper amounts and proportions. Although there are factors such as the ultra violet rays, which indirectly assist in maintaining the balance, the fundamental requisite is that the diet should contain calcium and phosphorus in the proper proportions, and should be of such a nature otherwise, that these can be absorbed through the wall of the gut, in the proper proportions.

Though the gross manifestations of disease due to the lack of such essential food constituents are more common in growing animals, they are not unknown in adult animals. On a long-continued diet deficient in calcium, the bones may be depleted of calcium phosphate to maintain the concentration of calcium in the blood which is necessary for the functioning of the soft tissues. McCrudden[5] in a recent review of the subject of osteomalacia attributes this disease to calcium deficiency, which, of course, was the view put forward by earlier workers. An interesting review of the early literature is given by Hutyra and Marek.

Some of the essential food constituents which are required in smaller amounts, are receiving attention. McGowan and Crichton[6] have shown that young pigs are liable to suffer from primary anæmia due to the lack of a sufficiency of iron in the food. The amount of iron required by the growing animal has not been determined by direct experiment, but estimations have been made. According to these estimates the amounts present in many foodstuffs commonly used for pigs are not sufficient to meet the requirements for growth in this species. Both the clinical symptoms and the pathological findings in the experimental pigs fed on these iron-poor foodstuffs, are those of a primary anæmia, and the disease, which appears to be not uncommon, can be prevented by the addition of inorganic iron to the food.

Smith and Denis[7] have found that a disease which causes a high mortality in new born pigs, and is associated with hairlessness at birth and with occasional malformations, can be prevented by the addition of small amounts of potassium iodide to the food of the sow. They attribute the disease to lack of iodine in the pastures in districts where the disease is common.

The balance of the different minerals in the ration has an important influence on nutrition. An excess of potassium may deplete the body of sodium. According to Zuntz[8], Schwartzwald hay, the consumption of which leads to a disease in cattle associated with skeletal changes, has a Na : K ratio of 1 : 178, while normal hay has a ratio of about 1 : 4. Recent work at the Rowett Institute by Dr Richards has shown that the Na : K ratio has an influence on the assimilation and retention of calcium and phosphorus during growth. Absolute or relative deficiency of sodium prevents the full utilisation of the calcium and phosphorus in the ration.

Ingle[9] working with horses, has shown that excess of phosphorus interferes with the assimilation of calcium. Even a full-grown horse may show pathological changes in the bones when the diet has a marked excess of phosphorus compared with calcium. This disease noted by Ingle is evidently the same as "Bran

Some of the essential food constituents which are required in smaller amounts, are beginning to occupy the attention of physiologists. McGowan and Crichton[6] have shown that young pigs are liable to suffer from primary anæmia due to the lack of a sufficiency of iron in the food. The amount of iron required by the growing animal has not been determined by direct experiment, but estimations have been made. According to these estimates the amounts present in many foodstuffs commonly used for pigs are not sufficient to meet the requirements for growth in this species. Both the clinical symptoms and the pathological findings in the experimental pigs fed on these iron-poor foodstuffs, are those of a primary anæmia, and the disease, which appears to be not uncommon, can be prevented by the addition of inorganic iron to the food.

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Rickets," a disease liable to occur in horses fed chiefly on bran, which has a ratio of P_2O_5 : Ca of about 10 : 1, compared with a ratio in good pasture of about 1 : 1.

It has always been known that the weight and vitality of the young at birth were dependent upon the nutrition of the mother during pregnancy. Recent researches have shown that this influence is much greater than had been supposed. Korenchevsky[10] working with rats, has found that the offspring of rats fed on a low calcium diet are more susceptible to rickets than those from rats fed on a high calcium diet. According to Zuntz[11], if the calcium deficiency exists long enough before conception, the whole development of the young is seriously interfered with. Urbeanu[12] has made the interesting observation that in fowls a calcium intake which is limited, but not to such an extent as to produce disease, either in the parents or in the first generation, may result in sterility in the third generation. McCollum,[13] in a recent review article on factors that interfere with growth, states that with deficiency of calcium "the first generation of animals may look fairly normal but will age early, their fertility will be low and infant mortality high, and the few young which grow up will exhibit deformities."

These examples are sufficient to show the importance of the mineral content of the ration for the preservation of health.

During the last few years a great deal has been written about the influence of "vitamines" on the rate of growth and the maintenance of health. There are in foodstuffs a number of compounds which can not be classed as proteins, fats, carbohydrate or mineral salts. The influence of many of them on metabolism has not been thoroughly investigated. There are also undoubtedly unknown substances which may have an influence on metabolism. These factors which do not fall within the known common nutritive constituents of food, have been much studied of late, and unfortunately have received the name of "vitamines," though we do not know whether they are amines or what relation they have with life. It seems probable, however, as has been suggested

elsewhere by the writer, that owing to our ignorance of the mineral requirements of animals, and of the influence of deficiencies or excesses of individual minerals in producing disease, much of the beneficial effect which has been accredited to vitamines is really due to the minerals present in the supposed vitamin-rich substances. Until our information is sufficient to enable us to draw up a basal experimental ration which is perfect with regard to the known constituents of food, it will be impossible to determine the extent to which disease may be due to the lack of these unknown constituents.

It is generally believed that the lack of these unknown substances is the cause of certain specific diseases, *e.g.*, scurvy, beri-beri, xerophthalmia. Rickets, sterility and many other diseases have been attributed by some writers to lack of these substances. In any case, the diet of farm animals consists chiefly of foodstuffs which are rich in these unknown substances, and it is unlikely that under practical conditions diseases due to lack of them would arise. The whole subject of these unknown substances is, however, of very great academic interest and warrants the attention of the clinician as they may ultimately assume some practical importance in veterinary medicine.

Dietary deficiencies as Predisposing causes of Infectious Disease.

Owing to the complication of symptoms by the activity of the invading organisms, the influence of dietary defects in predisposing to infectious disease is not so easy to trace as the direct uncomplicated results of these defects, such as have been referred to above. The predisposing influence to infectious disease is, however, probably of greater importance in clinical medicine than the more obvious direct effects of malnutrition.

The way in which predisposition to infectious disease arises is not quite clear. In certain cases there appears to be a depression of the vitality of the skin or mucous membranes which facilitates the entrance for bacteria when the power of resistance of the

animal is reduced through malnutrition. The gut swarms with micro-organisms, many of which are pathogenic if they succeed in obtaining entrance to the blood stream. Gastro-intestinal disturbances are usually the earliest, and are amongst the commonest symptoms produced by dietary errors. In the post-mortem examination of experimental animals which have been fed on a diet designedly deficient in some essential constituent, lesions of the wall of the gut, such as local congestion, oedematous swelling, or ulceration are almost invariably found. Further, it is known that the permeability of the wall to certain toxins, and possibly to certain bacteria, is affected by the concentration of certain inorganic salts in the intestinal contents. It is also known that the ebb and flow of fluid between the lumen of the gut and the blood is dependent upon the relative concentrations of electrolytes in these two systems. These conditions are controlled by the diet. Hence a long-continued improperly balanced ration, or a sudden change in the composition of the intestinal contents following an abrupt change in feeding may well precipitate conditions which facilitate the passage of toxins or bacteria into the blood-stream, even in cases where there is no demonstrable lesion, but where presumably there has been a reduced vitality of the mucous membrane. Invasion may take place. Rovsing[14] has emphasised the fact that tubercle bacilli can invade the mesenteric glands without any demonstrable lesion in the wall of the gut.

It is well known that, under certain conditions some animals develop diseases when the causal agent is derived from the intestinal canal of other animals, though harbouring the infection, do not develop the disease. The nature of the diet in these cases is most probably the predisposing and the most important cause.

There is now a great amount of direct experimental evidence to support the view that improper feeding predisposes to certain infectious diseases. Some of the more modern work in this connection is of special interest. McCarrison working with monkeys found that many of the animals on a diet of polished rice

which is deficient in several respects, developed dysentery, while control animals fed on a well-balanced ration remained free from the disease, though under similar environmental conditions and exposed to the same possibility of infection.

The influence of an imperfect dietary in increasing the susceptibility to the invasion of pathogenic organisms entering by the respiratory tract has been well shown by the numerous dietary experiments carried out in recent years. Theobald Smith[15] noted that guinea pigs, when on a ration of cereal grains, hay and carrots during the winter months, suffered a high mortality from pneumonia. He was in some doubt as to the relative importance of the seasonal variation and the diet. In some recent experiments with guinea pigs at the Rowett Institute, Dr Leitch has found that in a series of rations graded with regard to their nutritive value, where infection with bacillus bronchisepticus occurred, the incidence of the disease was closely correlated with the nutritive value of the ration. Those on a food of high nutritive value, although exposed to the same infection, did not develop any symptoms of the disease, nor was the bacillus recovered from the trachea at post-mortem examination.

Most workers who have conducted extensive feeding experiments with laboratory animals have noted the greatly increased susceptibility to pneumonia and other respiratory diseases in animals on an ill-balanced ration.

A connection between deficient nutrition and tuberculosis has long been recognised. In Germany at the end of the war the death rate from this disease had doubled. A predisposition to tuberculosis has been noted in experimental animals receiving diets which, though sufficient as regards energy supply and protein, are deficient in one or more essential nutrients.

Direct infection of the skin or exposed mucous membranes resulting in generalised infection or marked local lesions occurs very readily in experimental animals on deficient diets, though control animals under similar conditions develop no sign of lesion.

animal is reduced through malnutrition. The gut swarms with micro-organisms, many of which are pathogenic if they succeed in obtaining entrance to the blood stream. Gastro-intestinal disturbances are usually the earliest, and are amongst the commonest symptoms produced by dietary errors. In the post-mortem examination of experimental animals which have been fed on a diet designedly deficient in some essential constituent, lesions of the wall of the gut, such as local congestion, oedematous swelling, or ulceration are almost invariably found. Further, it is known that the permeability of the wall to certain toxins, and possibly to certain bacteria, is affected by the concentration of certain inorganic salts in the intestinal contents. It is also known that the ebb and flow of fluid between the lumen of the gut and the blood is dependent upon the relative concentrations of electrolytes in these two systems. These conditions are controlled by the diet. Hence a long-continued improperly balanced ration, or a sudden change in the composition of the intestinal contents following an abrupt change in feeding may well precipitate conditions which facilitate the passage of toxins or bacteria into the blood stream. Even in cases where there is no demonstrable lesion, but where presumably there has been a reduced vitality of the mucous membrane, invasion may take place. Rosenau[14] has emphasised the fact that tubercle bacilli can invade the mesenteric glands without any demonstrable lesion in the wall of the gut.

It is well known that, under certain conditions some animals develop diseases where the causal agent is derived from the intestine while other animals, though harbouring the infectant, do not develop the disease. The nature of the diet in these cases is most probably the predisposing, and the most important cause.

There is now a great amount of direct experimental evidence to support the view that improper feeding predisposes to certain infectious diseases. Some of the more modern work in this connection is of special interest. McCarrison working with monkeys found that many of the animals on a diet of polished rice

which is deficient in several respects, develop dysentery, while control animals fed on a well balanced ration remained free from the disease, though under similar environmental conditions and exposed to the same possibility of infection.

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Some of these lesions, such as xerophthalmia, may be correlated with specific deficiencies.

This accumulation of direct experimental evidence of the nature of that referred to here is sufficient to warrant the view that defective nutrition, as a predisposing cause of many infectious diseases, is as important clinically as the presence of the specific pathogenic organism which is the recognised determining cause. This view is in accordance with the conclusion reached by McCarrison[16] as a result of his investigation that "perfect food affords protection against the ravages of bacterial and other pathogenic organisms as adequately as does segregation or immunisation."

Probability of Dietary Deficiencies causing Diseases in Domestic Animals.

In modern conditions there are several factors which increase the probability of diseases occurring through dietary deficiencies. Two of these which are of special importance may be considered here.

During the last half century, types of animals have been bred whose young have a very rapid rate of growth and whose females have an enormous capacity for producing the constructive materials required for growth. A half grown pig may put on nearly 2lbs. of living tissue per day. Some cows can secrete in their milk as much as 10 or 12lbs. of solid material per day. Hens can lay up to 200 eggs per annum. This growth material used by the young, or produced by the mothers, is of very definite composition, and unless the diet is well balanced there is liable to be a deficiency of some constituents and an excess of others, even though the total energy value of the diet or the amount of protein present may be sufficient.

Concurrently with the evolution of these animals with a demand for an almost perfectly balanced ration, there has been an increasing use of concentrates, consisting chiefly of commercial by-products, of cereal grains of rich tropical seeds and nuts. The proportions of the various essential food constituents in these is very different from that found in mixed pasture which is the natural food of herbivora and

which, as investigations have shown, contains all the essential nutrients in approximately the proportions required for these animals. Consequently the diet during indoor intensive feeding is liable to be badly balanced, containing an excess of certain essentials and a marked deficiency of others. This lack of balance is specially marked with regard to the inorganic constituents (Orr)[17].

The extent to which dietary deficiencies are really responsible for diseases which are so prevalent in domestic animals is, unfortunately, as yet a matter of conjecture. Most of our definite information on the correlation of diet and disease has been obtained from experiments on laboratory animals and there is danger in the direct application of results obtained with experimental animals on abnormal diets, and kept under abnormal conditions, to farm animals fed and kept under practical conditions. There is available, however, certain information which in some cases, may be of practical value as a guide in preventing disease, and in other cases warrants the undertaking of further investigations under practical conditions.

There seems no doubt that in pigs, slow growth, rickets, anæmia, spasmophilia and increased susceptibility to pulmonary infections may appear as the direct result of improper feeding and that these diseases are of common occurrence in practice.

It has been suggested by the writer elsewhere[17] that the prevalence of tuberculosis in cows may be due in part to the failure of the ration to support the enormous milk yield. Meigs[18] has found that sterility and abortion are more common in cases where the diet is imperfect than where the diet has been well-balanced.

He suggests that dietary deficiencies may be predisposing causes of these diseases. An experiment with milk cows, which has been running at the Rowett Institute for the past two years, has given results which seem to confirm this suggestion, although it is too early to draw definite conclusions.

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and affections of the bones are amongst the most frequently occurring results of defective diets. Town horses are liable to be kept for long periods on monotonous diets which are frequently ill-balanced, and bony lesions are more common in street horses than in farm horses, which have usually a greater variety of food, including fresh pasture, which is the natural diet of the horse. It would appear to be worth while carrying out further investigations to determine whether, and to what extent, the health and length of life of the street horse are determined by the nature of the diet.

In the wild state the animal adjusts its diet according to its instincts and there are certain migrations of animals which seem to be associated with the necessity for a change in the composition of the herbage. The fencing in of natural pastures limits the free choice of the grazing animal. In several countries in the colonies it has been found that animals which remained healthy when allowed a wide range, suffered from various diseases of malnutrition when confined within limited areas. These diseases disappeared when artificial manures, which supply certain deficiencies, were added to the pastures. It is possible that in some of the natural hill pastures of this country which have not been treated with manures, there are deficiencies or excesses of one or more nutrients, and that these deficiencies have an influence on the incidence of certain diseases in sheep. During the past few years, Captain W. E. Elliot, M.P., and a team of co-workers, have been investigating this subject. The results so far obtained seem to indicate that there is probably a connection between malnutrition, due to the relative lack of certain essential food constituents in some areas and the incidence of disease in these areas. The whole subject, however, is one of extreme difficulty and it will be impossible, until there is a great accumulation of data to draw any definite conclusions.

Conclusion.

Although we now realise the importance of proper feeding in the prevention of disease, our information

with regard to what constitutes proper feeding and the evil results of different defects is still very meagre. There is urgent need for research to determine the requirements for all the constituents of food which are known to be essential, and the connection between specific defects and the correlated pathological phenomena. In these investigations the combined efforts of the laboratory worker, the clinician and the practical expert are called for. There is every indication that work of this kind would be exceedingly profitable. The results already obtained by work of this nature in connection with pigs, both in this country and in America, fully justifies a much increased effort in connection with all domestic animals.

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THE IMPORTANCE OF MINERAL MATTER IN NUTRITION.

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Minerals in feeding-stuffs which have received most attention from agricultural investigators are those of known value as fertilisers. These have been studied with the view of ascertaining (1) the extent to which the land is deprived of them by the growth and removal of crops, and (2) the extent to which the land is enriched by the manure made from animals fed with the various feeding-stuffs. In accordance with this limited view of the importance of mineral matter in feeding-stuffs, tables of food values commonly used in the present day state only the "total ash," or if certain of the constituents of the ash are estimated, they are dealt with under the heading of "manurial values."

Comparatively little interest has been shown by agricultural chemists in this country in problems relating to mineral metabolism and the mineral requirements of farm animals. Moreover the stock-feeders paid much attention to the subject. As a rule the only mineral salt they consider necessary to add to the food is common salt, and that is added usually more with the idea of providing a tonic or stomachic than of supplying needed nutritive material.

The neglect of this aspect of nutrition has been due chiefly to the fact that it is known that all commonly used feeding-stuffs contain considerable amounts of "ash" or total mineral matter, and it has been assumed that, on any ordinary ration, the needs of the animal for the various essential mineral constituents would be met. From the practical point of view,

therefore, it did not look as if the difficult and laborious researches required to determine the needs of the various animals for the ten or twelve essential minerals, and the effects of excess or deficiency of them on health, would yield results of sufficient practical value to warrant the expenditure of time and money on the work.

The results of recent research, however, have attracted renewed attention to this aspect of nutrition. It is beginning to be recognised that many of the problems of nutrition bearing on the economical use of feeding-stuffs, and also the incidence of disease, are intimately connected with the supply of mineral matter in the food. The subject is now of practical interest both to the stock-feeder and to the veterinarian.

In the present article, an attempt is made to give an outline of the importance of the functions performed by minerals in the animal body, of the extent to which farm-animals are liable to suffer from deficiency of them, and of the effects of such deficiencies. Unfortunately, it is impossible to give more than a fragmentary account of any of these aspects of the subject, as our knowledge of this aspect of nutrition is still scanty and, in some particulars, uncer-

The Rôle of Minerals in Nutrition.

Proteins (albuminoids) may be regarded as the basal material of protoplasm or living matter, and proteins, carbohydrates and fats as the sources of the energy and heat liberated by the activities of protoplasm. These three classes of substances are always present in animal tissues, and in the kinds of plants that serve as food for animals. Their importance has long been recognised. They have been termed the "proximate principles" of food, and in practice, in estimating the nutritive value of any substance, it is usually only these constituents that are considered. They all consist of the elements carbon, hydrogen, and oxygen, with, in the case of the proteins, the addition of nitrogen. The compounds of these elements, which form the three classes of food constituents named, have been called "organic constituents," because they are only found in living organisms, or in substances derived from living organisms.

But in addition to these four elements, all living tissue also contains calcium, sodium, potassium, magnesium, iron, phosphorus, sulphur, chlorine, iodine, and traces of other elements. When substances derived from living matter are burned, these remain and form the "ash." They are called the "mineral" elements. Their oxides, such as lime, the

calcium, and other compounds of them, as common salt, a compound of sodium and chlorine, are called the "inorganic constituents" of the body.

It requires to be emphasised that these so-called inorganic constituents of the body are as essential to life as the organic constituents. They stimulate and control, directly or indirectly, all the vital processes, and, consequently, they must be present in all living matter. Their fundamental importance in nutrition becomes evident, if we consider, as is done in the following paragraphs, the functions they perform in the body, and the disturbances that follow if these functions are interfered with through deficiency or excess of one or more of them.

The Necessity for a Proper Mineral Balance in the Body.

Not only must every organism contain these essential constituents, but they must be present in the body fluids and active tissues in definite proportions to form a physiologically balanced salt solution. Two such balanced solutions are sea-water and blood. The interesting results of the experiments of Jacques Loëb show how in sea-water the necessary balance may be destroyed by the addition of an excess of one of the vital elements. For example, the rhythmical swimming motion of a jelly-fish is stopped by the addition of relatively small quantities of a potassium salt or a calcium (lime) salt to sea-water.

In the case of the blood of animals, the need for maintaining the proper balance is even greater, because the fluid is part of the living organism. Here, the first condition to be fulfilled is the maintenance of the balance of minerals, so that the blood is kept practically neutral in reaction. Even a slight disturbance of the balance produces pathological phenomena. Increased acidity, for example, as occurs in certain diseases, is followed by disturbances of the respiratory mechanism and of the nervous system.

Even though the neutrality be maintained, excess or deficiency of any of the mineral elements affects the vital processes. Thus, in connection with the beating of the heart, a deficiency of potassium prevents the heart muscle from relaxing properly, while an excess makes it relax so completely that it stops beating. Not only must the concentration of potassium be correct, but there must be a correct proportion between the potassium and the other minerals.

All the other vital activities, to an equal extent, are, either directly or indirectly, regulated by the degree of concentration of the different mineral elements in the tissues and fluids of the body. Even slightly abnormal relationships

between certain of the mineral elements, unless rectified, lead to disease and eventually death. The first requirement of life and health is therefore the maintenance in the blood and tissues, of the ten or twelve essential minerals, in the proper amounts and proportions.

It is remarkable how efficient the animal body is in maintaining this physiologically balanced salt solution in the tissues, even when the food contains mineral matter of a totally different composition. The kidneys have the selective power of promptly eliminating minerals which are present in the blood in excess. On the other hand, those which are deficient are conserved. For example, chlorine, which is necessary for digestion, can be poured into the stomach to perform its function of aiding digestion, and be reabsorbed from the intestine. It can thus be used over and over again with little loss.

The bones act as a storehouse for retaining minerals (calcium (lime) and phosphorus, and probably other minerals) are brought out into circulation as required, and deposited again when the supply in the food is ample. The bones of this not merely dead inert girders. They are full of living cells which are always busy either laying down calcium phosphorus and other minerals as hard solid materials, dissolving them and passing them back to the blood stream again, according to the needs of the body. The function which the skeleton performs, in acting as a bank to regulate the supply of certain minerals to the fluids and soft tissues of the body, is almost as important as the more obvious function of providing a rigid framework. As will be seen in the case of calcium, or phosphorus, if the former function is neglected, the latter is sacrificed to meet the more vital requirements.

The means by which the neutrality of the body fluids is maintained are of interest. Acids are formed from the oxidation of sulphur and chlorine, and also from organic acids in the course of changes taking place in the tissues. These acids are neutralised by alkaline minerals—chiefly soda and potash. When there is not sufficient of these to completely neutralise the acids, ammonia is formed from the breakdown products of protein. The ammonia acts as a powerful neutraliser of the acids, combining with them and carrying them off in the urine.

In addition to these gross methods of adjusting the acid balance in the body, there are other finer adjusting processes in the fluids and tissues. These, however, need not be discussed here. Indeed, though they are known to be constantly in action, the biochemical reactions involved are not perfectly understood.

These powers of internal regulation of the mineral

the body enable the animal to tide over periods of feeding which the salts in the food are not adapted to the requirements of the animal. As a rule, it is only [illegible] continued [illegible] with a marked deficiency of one or more minerals that the reserves of these are exhausted. Under these conditions, the balance becomes so much upset that the regulating mechanisms break down, with disastrous results for the health of the animal.

The Functions of Minerals in Digestion.

The necessity of mineral salts for digestion has been shown by experiments carried out on the dog. If food be given, free from mineral salts, the animal becomes unable to digest it. After it has lain in the stomach for some time, it is found unchanged.

The flow of digestive fluids into the stomach and intestines is controlled, in part at least, by the concentration of minerals in the contents of the gut. Thus, in the upper part of the small intestine, increased acidity stimulates the flow of the alkaline fluid from the pancreas. The digestive processes are also affected by the acidity or alkalinity of the contents of the gut. For example, in the stomach the contents require to be acid to allow pepsin to act properly. To secure this, there is a secretion of hydrochloric acid into the stomach by the cells. This is one of the chief functions of chlorine in the animal body. The ebb and flow of fluid between the tissues of the gut and the blood-stream is controlled by the concentration of mineral salts in the intestinal contents and in the membrane lining the intestines. An increased amount of mineral salts in the intestinal contents tends to cause a flow of fluid from the blood into the intestine, which in some cases may cause diarrhœa. It is upon this action of the salts that the laxative effect of salts given as medicine depends. The laxative effect of bran is due to a like cause—to the presence of magnesium salts in the bran. If these be removed, bran ceases to be laxative.

The absorption of the products of digestion is controlled by the concentration of salts in the intestinal contents. It has recently been shown also, that certain minerals appear to exercise an influence in preventing or allowing the passage of poisons which set up disease if they reach the blood.

Even after the products of digestion have been absorbed and passed to the tissues, the utilisation of them depends on the inorganic constituents of the blood and tissues. The oxygen required for the combustion of the organic constituents is carried from the lungs to the tissues by haemoglobin, an iron compound. The carbon dioxide, a waste

product produced in the tissues, is carried to the lungs for excretion by sodium salts.

A consideration of these all-important functions of minerals in the digestion and utilisation of food, makes it easy to understand how conditions of malnutrition, referred to later, can arise when animals are fed over prolonged periods on foodstuffs either deficient in mineral matter, or with great excess of some and deficiency of others. It is not surprising that an animal fed on food free from minerals dies sooner than one in complete starvation, and that, while in the latter case death is peaceful and comparatively painless, in the former case it is attended by disturbances of the digestive system, convulsions, and distressing psychic symptoms.

Minerals as Constructive Material

In all animals there is a continuous loss of mineral matter in the excreta, and there must be a continuous supply in the food to make good this loss and maintain the proper level of the different minerals in the body. This amount has been termed the "maintenance requirement."

In growing animals, in addition to this maintenance requirement, minerals as constructive material must be supplied for the formation of bones and other tissues. Female animals, supplying the building material needed for the growth of bodies of their offspring obviously also require, as constructive material, a supply of minerals in their food. Hence growing animals, mothers suckling their young, and layers have a double need of minerals. As will appear later, these are the animals most liable to suffer from an inadequate supply.

The Amounts of Minerals Required by Animals.

When the importance of the mineral elements in nutrition has been appreciated, the two practical questions that interest the stock-feeder are—

(1) How much of the different essential minerals do various farm animals need?

(2) How much do the different feeding stuffs supply?

Our information with regard to the first question is fortunately scanty. The parts of the subject of most interest are the requirements for growth and for milk production. In both these cases, the most reliable figures are those obtained from calculations based on the composition of the body of the animal or of the milk. There is very little experimental data available.

Growth Requirements.

The two minerals required in largest amount for growth are calcium and phosphorus. About 75 per cent. of the ash of the body consists of these in combination as calcium phosphate. Of the ash of the whole body, above 80 per cent. consists of the oxide of these two minerals—calcium oxide (lime) and phosphoric acid.

In a store pig, lime constitutes about 1 per cent. of the live weight; in a bullock, about 2 per cent. The amounts of phosphoric acid are slightly less. Hence for every 100 lb. increase in live weight, the pig needs to build into its body about 1 lb. of lime and about the same amount of phosphoric acid. The calf needs double these amounts. In other words, a pig putting on 1½ lb. weight per day must absorb from the intestines and retain, quarter of an ounce of lime per day, and about an equal amount of phosphorus. A calf putting on the same weight needs double these amounts.

Unusually, only about 50 per cent. of the lime and phosphorus of the food can be absorbed and retained, so that the food should contain double the amounts needed as constructive material. The growing pig's daily ration should therefore contain about half an ounce of lime, and the calf's about one ounce.

Very little information is available with reference to the needs of the other mineral elements required by growing animals. The best guide to the amounts and proportions required is found in the composition of the ash of the milk of the species. Bunge has pointed out that this is adapted to the requirements of the young animal. The following table shows the close correspondence between the composition of the ash of the milk of the mother and of the ash of the body, in the case of a rapidly growing animal:—

	Percentage composition of ash of Rabbit 14 days old.	Rabbit's milk.
Potash	10·8	10·1
Soda	6·0	7·9
Lime	35·0	35·7
Magnesia	2·2	2·2
Iron oxide	0·2	0·08
Phosphoric acid	41·6	39·9
Chlorine	4·9	5·4

It has been seen from the table that milk is deficient in iron. To provide for this deficiency, the young are born with a large store of iron in their tissues to tide them over the suckling period.

The following table shows the approximate percentage composition of the ash of the milk of some species, and also

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the relationship that exists between rate of growth of the young of the species and the percentages of mineral matter and protein—i.e., the constituents used as constructive materials for new tissue formation :—

TABLE SHOWING RELATIONSHIP BETWEEN COMPOSITION OF MILK AND RATE OF GROWTH.

(Modification of table by Bunge.)

Species.	Time to double weight in days.	100 parts of milk contain					
		Protein.	Total ash.	Lime, CaO.	Phosphoric acid, P_2O_5.	Chlorine, Cl.	
Human	180	1·6	0·2	0·03	0·04	0·03	
Horse	60	2·0	0·4	0·12	0·12	0·03	
Cow	47	3·5	0·7	0·17	0·20	0·10	
Pig	18	7·2	1·1	0·41	0·35	0·12	

Notes.

(1) Sodium, potassium, magnesium, and sulphur are omitted from the table. Foodstuffs usually contain sufficient of these. They are therefore of special interest in the present connection.

(2) In this paper calcium and phosphorus are given as lime (calcium oxide) and phosphoric acid in the tables and wherever amounts of these minerals are mentioned because they are given as such in commonly used tables showing the composition of feeding stuffs. The term "lime," in preference to calcium, is used throughout this paper because it is more familiar to the non-technical reader.

It is interesting to note that the percentages of protein and total ash in the various milks are related to the rate of growth. The faster the animal grows, the greater the demand for these constructive materials. In practice it is found that the liability of animals to suffer from disease or malnutrition due to lack of minerals is greatest in those that grow fastest.

Assuming that protein and the different minerals are required by the young growing animal in the same proportions after the sucking period as during it, the amounts of the different minerals required by them can be estimated from the composition of the milk. In the case of farm animals this can be calculated from the above table, that in the milk of the species named, for every pound of protein there is something like an ounce of lime and about the same amount of phosphoric acid. According to the Wolff-Lehmann standard a young pig of 100 lb. weight needs half a pound of protein per day, and a calf of 500 lb. needs a pound. The former should therefore have about half an ounce, and the latter a full ounce per day of each of these two mineral constituents. This corresponds with the estimates given above, based on the composition of the full-grown animal and the rate of growth.

While estimates based on these calculations serve as guides, ...ing approximate average requirements, it should be kept ...view that animals vary in their requirements during the ...od of growth. The average over the whole period there- ...e might be an under-estimate for certain minerals for the ...ly period, when growth is most vigorous, and an over- ...mate in the later stages, when growth is slowing down. ...ividual animals and breeds also vary according to their ... of growth. A large amount of experimental work is ...uired to determine the actual amounts and composition ...mineral matter required for the different species at the ...ous stages of growth.

...e Rowett Institute (1) a number of such experiments ...been carried out on young pigs of the Large White Breed, ...amount of lime and phosphoric acid was determined by ...ses, in the food and in the excreta. The results for young ..., weighing about 100 lb., were in accordance with these ...lations. In these animals, which were at the stage when ...ily increase in weight was about the average for the ... period of growth, about quarter an ounce of lime and ...t more phosphoric acid were assimilated daily. But to ...se amounts assimilated, about half an ounce of each ...be present in the food. Until the results of further ...ments are available, therefore, it looks as if the com- ...n of the mother's milk could be taken as a useful ... the mineral requirements of young animals.

The Requirements of Dairy Cows.

...ilating animal requires minerals for two purposes: ...et the need for replacing the amounts lost in the ..."and tear" of her own tissues, and (2) for milk forma- ...The first need—the maintenance requirement—has not ...urately determined. Estimates have, however, been ...n Continental workers. According to these, translated ...English terms, a cow of average weight needs per day ...thing like an ounce and a half of lime and about four ...s of an ounce of phosphoric acid. The other mineral ...nts are required in smaller amounts, but the actual ...rements are not even approximately known.

...amounts drawn off from the body in the milk can be ...ated from the known average composition of the milk ...n of cows' milk contains roughly quarter of an ounce ... a third of an ounce of phosphoric acid, and a sixth ...ounce of chlorine. These are the three minerals most ...to be deficient in the food. In view of the fact that not ...than half of the mineral matter in the food is usually

...s and subsequent figures in brackets refer to bibliography at end of

assimilated, double these amounts should be present in the food for every gallon of milk

From these calculations, it is evident that a cow, giving four gallons of milk per day, needs for maintenance and for milk production a daily supply of three and a half ounces of lime, three and a third ounces of phosphoric acid, and something over an ounce of chlorine. Kellner's estimates of the requirements of lime and phosphoric acid are higher than these. He assumes that only about a third of the mineral in the food can be assimilated, and consequently he allows for milk production three times the amounts present in the yield of milk

The Supply of Mineral Matter in the Food.

The figures in the table on page 11, which gives the percentage amounts of certain minerals present in several representative feeding stuffs, are taken chiefly from the results of analyses carried out in Germany or in America. They can be regarded as giving only a rough idea of the amounts likely to be present in any actual sample. The mineral composition of plants varies with the nature of the soil, the climate, and the degree of maturity of the plant. Different samples of the same kinds of feeding stuff might therefore show considerable variations in the amounts and composition of the mineral matter present

The cereals are in general poor in lime and in chlorine. It requires about 10 lb. of a mixture of oats, bran, and maize in equal proportions, to yield half an ounce of lime, the amount needed by a three-months-old pig. They are, however, very rich in phosphorus. Of the cereals given, oats are the best balanced with regard to mineral matter.

Roots and tubers are poor in all the four mineral constituents given in the table, and especially in lime. They cannot therefore be regarded as supplying any substantial amounts of these essential minerals unless fed in large amounts

Fodders, consisting of the leaves and stems of plants, are rich in lime, chlorine, and iron, but relatively poor in phosphoric acid. Grains and fodders, therefore, tend to correct the mineral deficiencies of each other. The leguminous fodders are especially rich in lime: a pound of alfalfa hay yields nearly a third of an ounce

Meals and cakes vary in composition according to their source. In general, they are poor in lime and rich in phosphorus. Fish meal made from the bones and soft tissues of fish is very rich in mineral matter, which, in composition approximates somewhat closely that required for growth

formation. The same is true, of course, of the dry of milk residues.

Table showing the Mineral Composition of some Feeding Stuffs.

	100 parts contain				
	Total ash	Lime, CaO	Phosphoric acid, P_2O_5	Chlorine, Cl.	Iron oxide, Fe_2O_3.
	3·50	0·14	0·81	0·07	0·04
	1·50	0·02	0·69	0·07	0·01
	1·90	0·06	0·86	0·08	0·02
	6·30	0·99	2·95	0·09	0·03
	[illegible]	0·03	0·20	0·07	
	1·72	0·03	0·18	0·04	0·01
	5·80	0·08	0·08	0·04	[illegible]
	1·00	0·02	0·04	0·1	[illegible]
	8·60	1·95	0·54	0·1	[illegible]
	7·10	1·80	0·39	[illegible]	[illegible]
	4·90	0·25	0·31	[illegible]	[illegible]
	5·40	0·36	0·18	[illegible]	[illegible]
	5·20	0·29	0·13	0·20	0·03
[illegible]	8·2	0·38	2·67	0·04	0·8
[illegible]	5·6	0·51	1·70	0·09	0·14
[illegible] grain dried	[illegible]	0·06	0·68	0·06	[illegible]
[illegible]	6·80	0·29	1·37	0·13	[illegible]
[illegible]	21·00	10·00	9·00	0·50	trace
[illegible] dry matter	7·96	1·87	2·21	0·05	0·07
[illegible] water)	7·25	1·01	1·46	0·05	0·04

[illegible] variable, especially with regard to chlorine

[illegible] Deficiency of Minerals in the Food.

[illegible] been made in the preceding paragraphs to [illegible] functions which minerals perform in the animal [illegible] view of these, it is not to be wondered at that [illegible] follow when the requirements of the body [illegible] supplies in the food. Deficiencies [illegible] the bones and disturbances of the digestive [illegible] accompanying malnutrition and low [illegible]

In the wild state, herbivorous animals are not likely ... suffer from deficiencies. They have a free range, and ... choose their grazing according to their instincts, and so se... the mixed pasture necessary to yield an adequate supp... Under modern conditions the instincts of the animals ... less play. When they are grazed on natural pasture, as ... the case of sheep on hill grazing, the range is fixed, so ... the migrations that would naturally have taken place ... prohibited. In intensive stall feeding, the food consists large... of commercial by-products and other concentrates der... chiefly from seeds. The mineral content of these is ... different from that of a mixed pasture, which is the nat... food of the animals.

In the following paragraphs, the results of mine... deficiencies on the different species of farm animals are d... with, chiefly from the point of view of their economic im... ances.

Pigs

Potatoes and cereal products, such as maize, bran, and ... which are all commonly fed to pigs, are deficient in ... When fed on these, without the addition of lime rich fo... pigs are liable to suffer from soft bones and genera... nutrition. This condition, which is of the same nat... rickets, which occurs in children, was recognised as ... cause determined nearly fifty years ago by investi... in Germany. In the maize-growing areas of the ... States, great loss has been suffered from feeding pigs ... maize without the addition of some other food to make ... the mineral deficiency.

In Scotland, there is a well-known disease in pigs w... the young animals about three or four months old ... a rough staring coat, a stilted gait, loss of appetit... sometimes loss of power of the hind legs. In bad ca... fractures of the ribs and of the legs occur. The animals ... most liable to the disease. Recent inve... at the Rowett Institute (2) has shown that this disease ... closely allied to, if not identical with, rickets. It ... the want of balance in the mineral matter of the ... can be prevented by the addition to the food of a ... of inorganic salts which makes the mineral composition ... the whole ration somewhat similar to that of sows mi... Green food, milk, and fish-meal all supply the minerals ... lacking, and so help to prevent the disease. If the ... are allowed freedom, they usually find in pasture ... and the minerals lacking in their diet.

It will be understood, of course, that every pig ... legs " is not necessarily suffering from lack of mineral ...

... unfortunately, subject to many diseases that put it ... its legs.

... do not commonly suffer from lack of phosphorus, as ... most cases their food consists partly of cereal products, ... are rich in this constituent. Experiments have been ... ted, however, which show that, when phosphorus is ... stoppage of growth and paralysis of the hind legs ... occur. The condition can be cured in a few days by the ... tion of inorganic phosphorus to the food.

... rapidly growing pig requires considerable quantities ... In addition to a reserve store which it possesses at ... receives a more generous supply in the milk than ... animals. The percentage of iron in the milk may be ... ted by the food of the nursing mother. It is probable ... that the store of iron at birth may be affected by the ... of the mother during pregnancy. As sows are often ... food with very little iron, there is the probability of ... pigs suffering from lack of this essential mineral.

... has been investigated at the Rowett Institute. ... and Crichton fed breeding sows on distillery draff, ... and small quantities of fish-meal made from the bones ... ent flesh of white fish. This ration supplied suffi... and phosphorus, and probably also all the other ... needed except iron. The litters were born apparently ... but after the third or fourth week malnutrition was ...

The animals were breathless on exertion, and there ... number of sudden deaths. Post-mortem examination ... that the hearts were enormously enlarged. The blood ... and watery, and the haemoglobin—the iron-contain... of the blood—was in some cases only 15 per cent of ... Other sows were fed the same ration with the ... of iron oxide. The litters from these were perfectly ...

... investigations are being carried out by these ... Even from these preliminary experiments, how... looks as if shortage of iron might be the unrecognised ... of many cases of malnutrition occurring in pig-feeding. ... resting, in this connection, to note that cotton-seed ... been found to produce in pigs a disease characterised ... diarrhœa, loss of appetite, and coarse hair, and that ... tion of iron to the food prevents the disease.

... recent work done in America by Smith and others (3) ... of iodine, though required only in small amounts, ... of as great importance for health as lime or phosphorus. ... Mountain and certain other regions in the United States, ... in some parts of Western Canada, great loss has been ... through sows giving birth to young pigs not fully ... These were either dead at birth, or lived only a ... The most obvious abnormality was absence of ...

hair. An examination of the food from affected and affected districts showed that the foodstuffs grown in affected districts contained, on an average, less iodine than those grown in districts where the disease did not occur. The effect of adding iodine to the food was tried, and it was found that the addition of five grams of potassium iodide per day to the ration of each sow, for the last four or five weeks of the gestation period, led to the production of healthy litters from sows that previously had all had immature pigs. The amount of iodine required for the pig is unknown, but it is impossible to say whether the disease was due to a deficiency of iodine or to abnormality of the thyroid gland. The essential fact, however, is that addition of iodine to the food can prevent the disease.

The well known beneficial effect of feeding ashes to pigs is due to the fact that the ashes contain minerals often deficient in their food. Wood ashes may contain as much as 30 per cent of lime, and coal ashes as much as 5 per cent of iron. The rooting habit of the pig and also its liking for garden refuse, in the manure pit are doubtless associated with its need for mineral matter. The diet of herbivora contains much more mineral matter of the bodily and is therefore rich in lime and iron. The well recognised beneficial effects on the health of pigs of allowing them a free range over pasture are due to the fact that the animals have liberty to supplement their mineral deficiencies of their food.

Cattle

Growing cattle are not so likely to suffer from deficiency of minerals as pigs. If they are grazing, mixed pasture affords a good supply. In stall or yarding, hay and some other concentrates are usually fed. The former, especially clover, is rich in lime and iron, the latter in phosphorus. In intensive feeding, however, where a large proportion of concentrates rich in flesh and fat forming materials is given, and where, consequently, there is rapid growth, the bones may remain weak through deficiency of lime. Care is taken to adjust the ration by the addition of such foodstuffs as silage or clover hay.

It is very probable that calves weaned early often suffer from lack of sufficient mineral matter. They are fed on slops made with meals derived from the cereals that are too rich in phosphorus and too poor in lime. Linseed meal, which has been found to be excellent for young calves, is especially rich in lime and iron, to which doubtless its excellency is largely due. There is, of course, no question as to which calves will thrive so well as on cows' milk which contains all the minerals in the amounts and proportions

growth. The mineral most likely to be deficient in calves' food is lime, and Kellner recommends that calves should get an extra supply of lime even when receiving milk.

It is surprising how little attention has been given to the mineral requirements of the dairy cow. This is probably the most important of all the problems in animal nutrition, and one of the most difficult. It is an easy matter to calculate from the milk-yield and the known composition of milk the amount of the different minerals drawn from the cow per day, and to calculate the supply in the food. If, as is often the case, the bulky food such as hay, straw, and turnips be regarded as the maintenance ration, and the concentrates, such as cakes, grains, &c., be regarded as the milk-producing portion, and fed to the animals in accordance with the yield, then the mineral composition of the concentrates should bear a close relation to the mineral composition of the milk. In practice, most concentrates show an excess of some minerals and a deficiency of others. Lime is especially lacking. In cases of low milk yield the deficiency is not so serious, especially if hay or silage be fed, because these contain more lime than is necessary for maintenance, so that some is available for milk production. The higher the yield, the greater is the difference between the supply in the food and the demand for milk, and the greater is the drain upon the cow's skeleton to make up the supply in the milk. In the spring, when the cows are put out to grass, they receive in the pasture an abundant supply of the minerals which are usually deficient in the winter food. They are thus able, to some extent, to refill the depleted reservoir in the skeleton.

One part of this subject that has received most attention of late is the influence of common salt (sodium chloride) in the diet of the cows. The liking of ruminants for common salt has long been recognised, and the "salt lick" is frequently provided for cows, with the idea that it whets the appetite and aids digestion. Experiments carried out at Wisconsin Experimental Station, U.S.A., in 1905[4], showed that the beneficial effects are due to the supply of chlorine in the salt, and that the animals that suffer first when deprived of salt are the heavy milkers—i.e., those requiring most food to keep up the supply in the milk. In these experiments the signs of malnutrition appeared, in some cases in a month, and in other cases not until almost a year's deprivation of salt. When the breakdown occurred, there was a sharp fall in the milk yield, loss of body weight, poor appetite, and a "generally haggard appearance," with brittle hair and a rough coat. A rapid recovery followed when salt was supplied, either as sodium chloride (common salt) or as potassium chloride.

Comparatively little experimental work has been done to

determine the effect upon health and milk-yield of the lack of other minerals. But a number of observations have been recorded of cases of malnutrition occurring in practice and attributable to this cause. Some of these are instructive.

In Bihar in India, according to Davis (5), the native cattle have a very low milk-yield, 3 to 5 seers, compared with 15 to 20 seers in certain other parts of India. The low yield is not entirely due to the breed, because the yield of good milking cows from other districts decreases to nearly the same low level after being brought into Bihar. The crops raised in this State are very poor in phosphorus, owing to the low phosphorus content of the soil, some samples of which have only about 1 per cent of the amount present in certain fertile areas in Europe. A gallon of milk contains about a tenth of an ounce of phosphoric acid. On a diet so deficient in phosphorus, therefore, it is not to be wondered at that the milk flow is at a low level.

In Wood's Therapeutics (6) a case is recorded of a herd of cows which, after being fed for a long time on hay from a certain meadow, suffered from ill-health and soft bones. An examination of the hay showed that it was markedly deficient in mineral matter. Bone meal was fed, and in about a month the animals recovered their health.

Forbes, of the Ohio Experimental Station, U.S.A. (7), has observed evidence which shows that failure to breed is more common in dairy cows than in beef cows, and among the former the heavy milkers with long lactation periods are especially liable to sterility. It looks as if, in those cows, the drain from the tissues of the body, of the minerals required for milk production, reduces the animal to a state of sterility in which reproduction is impossible. Unfortunately there are no definite figures available on this subject. Statistics showing the relative frequency of sterility in the following two extreme cases would be instructive: (1) heavy milk-yielding cows grazed in summer on good mixed pasture, and fed in winter chiefly on silage and mixed clover hay, roots, and cereals; (2) cows with rations of straw, turnips, and distillery wash, compared with the former rations, markedly deficient in mineral matter.

The writer has for some time been endeavouring to obtain definite information in regard to the correlation between the nature of the food and milk yield, and the liability to contract tuberculosis. The necessary information is not yet as satisfactory as on many dairy farms with high milk yields tuberculin tests are not carried out; and in the information available is for the most part of an indefinite nature and not entirely trustworthy. So far, however, the available information seems to indicate that the milk

nature of the food affect the susceptibility of the cows to tuberculosis, and are as important factors in the incidence of the disease as the nature of the housing.

The heavy milking cows seem to be definitely more susceptible to tuberculosis than those with a low yield. In Lord Astor's model dairy farm at Cliveden, where investigations data is being accumulated, the records seem to indicate that there is a definite correlation between milk yield and reaction to the tuberculin test.

The information with regard to the influence of the diet, though scanty and lacking in precision, seems to indicate that cows fed on ill-balanced rations, consisting mainly of dairy grains, meals, and cakes rich in protein (albuminoids), which stimulate the flow of milk, and poor in certain minerals required for the milk, succumb earlier to the disease than those with a good mixed ration containing foodstuffs rich in well-balanced minerals such as silage, hay, and fish-meal.

The prevalence of tuberculosis in dairy cows causes such heavy loss to the farmer, and is such a danger to the public health, that every possible factor that affects the susceptibility of the animal to the disease should be investigated. Although the evidence presented here is totally inadequate to establish even a definite opinion with regard to the influence of the deficiency of mineral matter on the susceptibility to the disease, it is sufficiently suggestive to warrant mention. If sufficient interest were taken in the dietary aspect of this problem, experiments might be made by the many highly-skilled practical experts who now conduct the dairy industry, and information accumulated which might ultimately be of practical value.

The Horse.

The mineral requirements of the horse have received even less attention than those of the cow. But there is a certain amount of well-established information that shows the importance of mineral matter in the diet of the horse. There is a consensus of opinion that certain districts are more suitable for rearing horses of good bone, and that districts the soil, and consequently the pasture and crops grown on the soil, are rich in lime and in phosphorus, the minerals needed in largest amounts for bone formation. There is definite evidence to show that diseases, chiefly affecting the bones, are produced by foodstuffs with excess or deficiency of certain minerals. "Bran rickets" or "miller's disease" is caused by feeding excessive amounts of bran, which contains an enormous excess of phosphorus and deficiency of lime. Ingle (8) has shown that in South Africa a disease very similar disease occurs in horses in certain districts.

where the pasture and fodder crops have a great excess of phosphorus and a deficiency of lime. On the other hand, deficiency of phosphorus in the feeding-stuffs, as occurs in Bihar in India and in certain other regions, leads to a disease characterised by loss of co-ordination and of muscular power in the hind limbs and to porosity of the bones. This disease is probably the same as that referred to above as being produced experimentally in pigs on a phosphorus-deficient diet.

In street horses, affections of the bones of the legs are much more common than in farm horses. It has been perhaps too hastily assumed that the hard nature of the road and strenuous work are alone responsible for the lesions in the bones. In the former case. From the known requirements of the animal, one would expect that the food should contain lime and phosphoric acid in about equal amounts. But the street horse is usually fed on foodstuffs with a large excess of the latter. Oats, the best balanced of all the grains, has about six times as much phosphoric acid as lime. Bran has thirty times as much. Further, the street horse is kept on the same ration for long periods. The continual excess of certain materials and deficiency of others is bound eventually to affect the texture and the composition of the bones, rendering them softer and more liable to injury.

The farm horse, on the other hand, receives usually a greater variety of feeding-stuffs. For the great part of the year, also, it gets a certain amount of grazing, and the mineral content of the pasture supply what is liable to be deficient in the feeding. If not infrequently happens that a street horse in bad condition, when put upon a farm, shows after a few months a marked improvement in its limbs. The improvement is probably due as much to the change in the diet as to the change in other conditions.

The quality of the bone affects to a great extent the soundness of the horse. It has been shown by carefully conducted experiments that in the case of the pig the hardiness and density of the bone can be markedly increased by increasing the mineral content of the food by the addition of mineral salts. There is no difficulty in getting the horse to eat such salts incorporated with its food. It would be worth investigating to what extent the bone of the horse is affected in this way.

Sheep.

There is very little exact information with regard to the extent to which sheep under practical conditions suffer from deficiency of minerals. Though the requirements of the animal of the different minerals have been determined by experiment, we have little information about the supply of minerals in the food. Sheep are grazed very largely on natural pastures,

the mineral composition of which is unknown. Several experiments with hand-fed sheep have been done, however, which show that the mineral content of the food is of great importance. Some of these may be referred to.

Sheep require considerable quantities of chlorine. It is most probably this need for chlorine that causes the liking for common salt (sodium chloride). In an experiment carried out in France (*) the beneficial effect of supplying salt to hand-fed sheep was shown. Sheep which received half an ounce of salt per head daily made greater increases in weight, and had heavier and better fleeces than sheep on the same ration without salt.

In an experiment carried out by Captain Elliot at Lanark during the winter of 1921-1922, it was found that on a ration of turnips, swedes, oats, distillery grains and linseed cake with cod-liver oil, the addition of a lime-rich mineral salt resulted in about 20 per cent greater gain in weight than in control sheep receiving no additional mineral matter.

A most striking example of the way in which mineral matter affects the health of sheep occurred in Michigan, U.S.A. In that State the sheep-rearing industry suffered great losses by the prevalence of goitre. With the discovery of salt deposits round the Great Lakes, and the use of salt for sheep, the incidence of the disease rapidly decreased. It is most probable that the prevention of the disease was due to iodine which is in the salts.

The results of an experiment with breeding ewes carried out during the winter of 1921-1922 at the Rowett Institute show that the excess of certain minerals may have evil effects. Two groups each of twenty ewes, were penned in, on about half an acre of pasture, and fed on straw, hay, swedes, oats, and cake. One group received, in addition to the ration, eight drachms (nearly a third of an ounce) of a soluble lime salt (calcium chloride) per head, per day, during the whole gestation period. In this group only six living lambs were got from the twenty ewes, compared with twenty-one in the other group which had no lime salts. The lambs in the salt group were, moreover, on an average, about 12 per cent heavier at birth. It is probable that the excess of calcium chloride had irritated the uterus, causing it to contract irregularly, as a number of the ewes aborted, and there were many cases of malpresentation at birth.

The results quoted here show that, in the sheep, the mineral content of the food may have a profound influence on the rate of growth, quality of fleece, and fecundity. Unfortunately, the exact influence which excess or deficiency of the various minerals may have has not been studied, nor have we definite information with regard to the mineral content of natural pastures, which form so large a part of

the diet of sheep. We do know, however, that the composition of the soil is reflected in the mineral composition of the plants grown on it. In the natural state, the sheep was free to wander over wide areas with different geological formations, and could follow its instincts in the choosing of its feeding ground, so that deficiencies in pastures in one area might be made good in subsequent grazing in another area. Under modern conditions, where sheep are confined in limited ranges, it is quite possible that in some districts they suffer from excess or deficiency of one or more minerals to an extent that affects the rate of growth of the animal, the quality of the fleece, and also the health.

The idea of the composition of the soil having an influence on the nutrition of the sheep is by no means new. Brown in his work, 'British Sheep Farming,' 1870, puts forward the suggestion that the character of the soil has been an important factor in the evolution of the different breeds of sheep, and several workers have traced a connection between the character of the soil and the quality of the fleece.

Poultry.

The need of laying-hens for an abundant supply of lime for formation of egg shell has long been recognised. Oyster-shell or some other source of lime is supplied to laying-birds by all intelligent poultry-keepers.

It is interesting in this connection to note that the laying of shell-less eggs is due to some cause other than lime deficiency. The shell is absolutely essential for the development of the chick, because it supplies lime for bone formation. The supply in the food is inadequate, so long as the hen continues to lay she will, if necessary, deplete her own bones of lime to provide for the shell, though in deficiency of lime the supply may be conserved by the shell being formed thinner than usual.

But the bones are not an inexhaustible reservoir, and ultimately the rate of egg-production must slow down to the level at which the food can supply the necessary material. When there is insufficient lime in the food, therefore, the production is less than when an ample supply is provided. This is well shown by experiments conducted in 1917 at the Kentucky Experimental Station, U.S.A.(10). Hens were kept in different groups with no access to the ground. The food consisted of maize meal, bran, middlings, meat, and chaff as mash, and for grain, maize, wheat, and oats. Two groups were given each oyster-shell or limestone. The egg-production in these two groups was, on an average, 69·4 per cent. greater than in the groups receiving no extra mineral matter.

Though lime is the mineral most likely to be deficient in

poultry foods, phosphorus, chlorine, and, on certain rations, other minerals may be lacking in sufficient amounts, and the rate of growth, egg-laying, and hatchability of eggs thereby affected. At the Ohio Experimental Station (11) some recent work showed that even when oyster shell, and green food in the form of sprouted oats, were supplied in unlimited amounts, the addition of a mineral mixture consisting of five parts bone phosphate to one of common salt and one of chalk increased the value of the ration for growth and egg-production by more than 40 per cent.

Reference has been made to the value of iodine for the prevention of certain conditions of malnutrition in pigs and sheep. It has also an influence on poultry. The results of experiments at Wisconsin (12) seem to indicate that the addition of iodine to the food helps to prevent the laying of soft-shelled eggs. It is very probable that iodine has some controlling influence on the metabolism of lime salts in the body. Oyster shell contains some iodine. This may account for its superiority over lime as a source of mineral supply for poultry.

It is obvious that attention to the mineral content of the food of poultry would be repaid by increased profits to the poultry-keeper.

The Mineral Content of Pastures.

An important feature of the problem of securing an adequate supply of minerals in foodstuffs is the variability of the composition of plants. Vegetation to some extent reflects in its mineral composition the character of the soil on which it is grown.

The part that varies least is the seed. But even in the amount of phosphorus present may show variations of 50 per cent. In the leaves, the variation is much greater. Scott (13) in 1919 analysed two samples of crab grass (*Digitaria sanguinalis*), one grown in a garden and one in a limestone roadway. Though there was no observable difference in external appearance, the sample from the limestone road contained 44 per cent more lime and 22·7 per cent less phosphorus than the one from the garden.

Many cases of malnutrition in animals due to mineral deficiency of pastures have been recorded. Reference has already been made to the low milk-yield of the cows in Bihar, where the soil has an abnormally low content of phosphorus. In the Hawaiian Islands, where the soil is of volcanic origin and very little lime, cattle have a slow rate of growth, and cows yield very little milk. The feeding of bone flour or lime-rich foods improves the condition of the animals, and enables stock-rearing to be conducted with profit.

In certain parts of Australia the natural vegetation is poor in phosphorus, and the characteristic bone lesions and paralysis associated with deficiency of this mineral are common. Milk cows and growing stock are worst affected. Murphy (14) gives an account of the impossibility of keeping cattle in good condition in certain districts after the land was fenced and the areas on which the animals could graze restricted. When, however, the soil was fertilised with the deficient mineral, the live stock could be maintained in good condition. Several somewhat similar cases of malnutrition in animals due to deficiency of mineral matter in the pasture are recorded in the older German literature.

These examples serve to emphasise the importance of the mineral composition of pastures. There appears to be a certain relationship between the composition of the ash of pasture and their feeding value. Thus an admixture of clover improves pasture, because it increases the amount of lime. Clover contains four times as much lime as phosphorus and, on the other hand, cattle will not thrive on a purely clover pasture because the amount of lime is too high compared with phosphorus. It is almost certain that within the next few years it will be demonstrated that the best pasture is that whose mineral content is balanced to suit the animals grazing on it, and that the mineral matter of the crop to be grown should receive as much consideration as the bulk of the crop.

We have put forward here the view that the composition of the mineral matter of pasture is an important factor in determining its value for nutrition from some recent observations made in connection with the nutritive value of [illegible] mineral matter of foodstuffs.

It has been proved by feeding experiments that cereals, in addition to proteins derived from animal sources are also rich in protein concentrates rich in protein derived from vegetable sources. The superiority of the former has been ascribed entirely to the better quality of the animal protein. Recently, however, experiments (11) carried out in the Rowett Institute have shown that the inferiority of certain vegetable proteins is not so much due to the quality of the protein as to the fact that they are associated with a deficiency of mineral matter. For example, maize supplemented with a suitable mineral mixture, gave as good results in the feeding of young chickens as maize supplemented with animal protein from meat scraps or from butter milk. Similar experiments carried out in the Rowett Institute have also shown that when either fish-meal or blood meal is added to a mixed grain ration for pigs, the animals receiving fish meal made greater gains in weight and kept in better health than those getting the blood meal. When, however, the

ration with the blood-meal was supplemented with a mineral mixture to make it resemble the mineral-rich fish-meal, growth and health were as good as when fish-meal was fed. It was concluded that the superiority of fish-meal as compared with blood-meal is due to the mineral matter it contains.

Remarkable results in nutrition have been attributed to vitamins. Recent experiments carried out at the Rowett Institute have shown that similar results can in many instances, in the pig at least, be obtained by the addition of minerals to the food. It has been found that the more closely the mineral composition of the food is adjusted to the requirements of the animal, the less is the influence of vitamin-rich substances on health and rate of growth. In some cases, the beneficial results attributed to a vitamin have in reality been due to the mineral matter in the foodstuff supposed to be rich in that vitamin. For example, much of the value of green food, which has been thought to be chiefly due to its wealth in vitamins, is due to the fact that the minerals present make up the deficiencies of grain and other concentrates. The matter has dealt with this subject in some detail in another publication (15).

It must not be assumed, however, that all proteins are of equal value, or that vitamins are non-existent. Animal proteins are, in certain combinations, of more value by reason of their quality or composition than vegetable proteins, and there are in foodstuffs unidentified substances of properties which have a profound influence on health and rate of growth. Much confusion has been caused by workers who failed to appreciate the importance of the mineral matter in the foodstuffs, and attributed to hypothetical vitamins beneficial effects that in reality were due to mineral constituents of the food given as a source of the vitamins.

Mineral Deficiency and Disease.

Reference has been made in the foregoing paragraphs to conditions of malnutrition resulting from lack of essential minerals in the food. Ill-health due to this cause is, without doubt, exceedingly common. It varies in degree from a hardly noticeable lack of the "bloom" which is characteristic of an animal in proper health, to a state like rickets, with gross disease so obvious that it can be termed a disease.

A frequent accompaniment of this form of malnutrition is a depraved appetite, which causes the animal to chew and swallow various objects. Thus hens pick each others feathers to chew and swallow wool. This craving is most probably

due to an instinctive attempt on the part of the animal to make good a mineral deficiency in its body, and is of the same nature as the salt hunger of herbivora and the rooting habit of the pig. The writer has observed that pigs on an experimental ration, with insufficient lime, frequently acquire the habit of drinking each other's urine, and when liberated make at once for some lime-rich substance, such as coal, ashes, or the dung of herbivora.

An interesting example of this symptom, which is known as "Pica," occurs in Lamziekte, a disease which was very prevalent in South Africa. The cattle develop the disease from pathogenic organisms, which they get from chewing putrefying carcases. It has been found that the abnormal craving is caused by a lack of phosphorus, owing to the low phosphorus content of the pastures in the districts in which the disease occurs. When bone-meal or any other phosphorus-rich substance is supplied to the animal, the craving for bones disappears.

An important aspect of this part of the subject is the influence of the feeding of the mother on the health and vitality of the offspring. Researches carried out in America in 1921 (17) have shown that in rats, on a diet deficient in lime, the percentage of fertility at mating was reduced from the normal of 65 per cent to 31 per cent. Somewhat similar results have been recorded in the case of cattle and pigs. It has been noted that deficiency of lime during the gestation period may be followed by the birth of either a dead calf or a weakling. The same sequence of events occurs in brood sows. The effect of the lack of iodine in the diet of the sow on the litter has already been discussed.

During the lactation period, the mineral content of the food of the mother is hardly less important. It has been too readily assumed, from the results of short period experiments, that the composition of the ash of milk is unaffected by the nature of feeding. It has been recently shown that the milk of cows fed on pasture has, for growing animals, health promoting properties to an extent not shown by the milk of stall-fed animals receiving no green food. American workers in 1920 carried out certain experiments (18) that showed that the composition of the ash of the milk is different in the two cases. The four minerals most likely to be deficient are lime, phosphorus, chlorine, and iron. The following table gives the percentage of these four in pasture-fed cows and in cows fed on meals, beet pulp, molasses, and straw.

	Pastures.	Meals, straws, &c.
Lime	0·165	0·138
Phosphoric acid	0·190	0·158
Chlorine	0·097	0·054
Iron	0·0002	0·000[illegible]

IMPORTANCE OF MINERAL MATTER IN NUTRITION.

An understandable reason for the superiority of milk of pasture-fed cows is thus afforded. The milk yields larger quantities of those minerals most liable to be deficient in the food of growing animals.

The influence which long-continued deficiency of mineral matter in the food may have upon the incidence of disease, due to microbic infection, is well worthy of consideration. We know that the alimentary canal is swarming with pathogenic organisms which, if allowed to pass through to the blood stream, cause disease. We know also that the concentration of salts in the intestines determines the ebb and flow of fluid between the contents of the intestines and the blood, and that lime salts control the permeability of the wall of the intestines with regard to certain substances, including, possibly, invading infective agents. It is very probable that a long-continued wrong balance of minerals in the food, or a sudden change in the mineral content of the intestines, brought about by a sharp change of diet, may produce such a condition that infective organisms, normally kept from entering the blood stream, are allowed to pass through and produce acute disease.

Another aspect of the problem of the prevention of diseases, due to pathogenic organisms, is the resisting power of the animal. There is nothing more striking in the recorded results of experiments in connection with deficiency diseases than the frequency with which the animals on the deficient diets suffer from infectious diseases—*e.g.*, pneumonia, infective sores, inflammation of the eyes, and in some cases tuberculosis. The body in perfect health has powers of resisting these diseases. In conditions of malnutrition, however, the vitality is lowered, and the resistance to infection decreased. It seems possible that the best defence against many of these infectious diseases is a perfect state of nutrition, and the most frequent dietary cause of malnutrition of farm animals, so far as our present knowledge is available, appears to be connected with the mineral matter of the food.

The practical problems of nutrition are more and more coming to be connected with the problems of disease, and it is probably from the joint efforts of the nutritionalist and the veterinarian that the greatest advances in connection with the prevention of disease will be made.

NEED FOR FURTHER RESEARCH.

The foregoing paragraphs have served to reveal our ignorance of the subject of the mineral aspect of nutrition, rather than to give exact information. From what we do know, however, it appears certain that excess or deficiency of cer-

ain minerals in the food may have a profound influence on the health of the animal. But we do not yet know with certainty what constitutes excess or deficiency. Further experiments must be conducted to determine the amounts of each essential mineral required by the various farm animals and the influence on nutrition of excess or deficiency. More information is required also regarding the mineral composition of feeding stuffs.

Even when this information is available, other and even more difficult problems remain to be solved. Minerals may be present in the food, but in a form that cannot be absorbed. Forbes has shown that lime may be present in the food of the dairy cow in ample amounts, and yet the animal may continue to lose lime from its tissues. Assimilation is affected by other constituents of the diet. Thus, cod-liver oil influences the percentage assimilation of both lime and phosphorus. So does also the ratio of these minerals to each other, the degree of acidity of the ration, and most probably other factors not yet recognised. Hence the provision of sufficient mineral matter in the food is only part of the problem. The other part of the problem is to secure that the whole ration is so balanced that sufficient mineral matter will be assimilated. This involves years of laborious work on the part of physiologists, biochemists, and pathologists, and also of practical experts, who frequently have knowledge which is invaluable as a guide to investigators.

The Value of Salt Mixtures.

During the last two or three years various salt mixtures have been advocated and some put on the market. It is obvious to the intelligent reader that, though these may do good in some cases, they do not solve all the difficulties. An adequate mineral supply. In some cases, indeed, they may do harm. For example, a salt mixture rich in phosphorus would show excellent results if added to a ration poor in phosphorus, but would do harm if added to one with a surplus of phosphorus. Salt mixtures intended to be used in a routine way with all the different kinds of rations likely to be fed are quack remedies of doubtful value. There is no short cut to the perfect feeding of animals. The feeder must know the requirements of his animals, and the extent to which different feeding stuffs will meet their requirements, and then arrange rations accordingly. The research worker may ultimately be able to supply him with the necessary technical information to do this. But he will never be able to supply him with a salt mixture that will relieve him of the necessity for making his own calculations, and coming to his own decisions as to what is best for the animal in each case. Indeed, that is where the skill and [illegible] the feeder comes into play.

Note.—The author wishes to acknowledge his indebtedness to Miss [illegible] Schertzoff for assistance in drawing up the tables in the paper, and for arranging and verifying the list of references.

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Kenya

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Strachey.
J. Shuckburgh
Davis.
J. Grindle.
H Lambert
~~Masterton Smith.~~
Ormsby-Gore.
Amery.

Ptd for Hr. Ormsby-Gore's Sig.

RAFT.

1st July 1925

Elliot,
, M.P.

My dear Elliot

Many thanks for your letter of the 21st of June about the proposed visit of Dr. Orr to Kenya. We now propose to send copies of the correspondence to the Acting Governor of Kenya, asking him to report by telegram whether he agrees to the scheme, and if so requesting that he will go

for any information bearing
on the subject which the
Agricultural Dept may
be able to collect to be
sent home at once (Mr Harrison,
by the way, is the Deputy
Director of Agriculture The
Director of Agriculture is Mr.
A Holm) Copies of the

Copies of the correspondence
will also be sent to the
Governors of Uganda and
the Tanganyika Territory,
asking them to report whether
they would like the tour
to be extended to those
Countries, should this be
found to be practicable.

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Anderton Smith.
[illegible]

RAFT.

and requesting that in that
event any useful information
available locally may be sent
192

But before we write to
the Governors there are one
or two points in connection with
the financial aspect of the
scheme which I should be
grateful to have cleared up.

First, as to passage expenses.
It is presumably only expected
that the East African Govts.
should pay the extra cost
involved by Dr Orr's visit
to East Africa. The figure

seems rather large for this and I assume that it approximately represents the travelling expenses for the whole tour. Is this right? And if so does the 42 days for which subsistence is allowed include the stay in South Africa?

Secondly as to the scientific secretary. It is rather hard for us here to decide whether there should be one or not. If one is accompanying Orr to South Africa in any case, it will obviously be convenient for him to go to East Africa also, and we will definitely put this to the East African Governments as part of the scheme. But if you would not be sending a secretary

Offices 10/7/25 28572/25 MRE 362

Bottomley 11.7 for action

and

Sir J. Shuckburgh
Mr C. Davis.
Sir G. Grindle.
Sir J. Masterton Smith.
Mr Ormsby-Gore.
Mr Amery.
for consn

Copied group 11/7/25
V. to Offices

DRAFT. Tel. code July (1925)

Sir

Governor

Nairobi 11 July In connection with ~~proposed~~ proposal

~~early visit~~ as to which despatch

follows ~~of~~ that research worker

desires of carrying out work

on mineral content of pastures

should visit Kenya in autumn I

shall be glad if you can

arrange for twenty three pound

samples of grass from

highland grazing areas

to be collected and sent

Colonial Office
8.40 pm
22nd Sept '24

25073

2nd

Confidential

C. D.
R 23 SEP
D 24th

DRAFT Confidential

Governor
Nairobi

MINUTE.

Mr. Montgomery
Mr. 22.9.24 date
Mr.
Sir. J. Shuckburgh.
Sir C. Davis.
Sir G. Grindle.
Sir J. Masterton Smith
Lord Arnold.
Mr. Thomas.

A.R.C.A.

at request of
Montgomery Colonial
Office)

May tel: of 11th Inst
pasture grasses
should be glad to learn
when samples may be
expected & Early receipt
desirable.