

conditions. There are two large laboratories for the preparatory and advanced stages of this special study of non-ferrous metals as used in the Sheffield trades. The lecture-rooms are two in number, one seating 150 and the other fifty students, both being provided with up-to-date electric lantern arrangements.

The micrographic laboratory has been made to a specially thought out design, each block of the polishing battery being run by a separate electric motor of one-seventh h.p., revolving at 1400 revolutions per minute. Adjacent to the polishing and etching-room is a photomicrographic department complete with dark-room. The photomicrographic apparatus is by Zeiss, and is fitted with the new arc lamp of this firm. There is a large staff and research laboratory, one side of which is devoted to calorimetric work.

From the point of view of pure science the most important installation in the new metallurgical wing is a specially devised recalcence laboratory for observing with great accuracy the critical points of iron and steel, the freezing points of metals, and the phenomena of solid solution in metals. There are coke-fired and electric vacuum furnaces in which a complete vacuum can be obtained in about one minute by means of the "Fleuss" pump. The recalcence apparatus comprises an astronomical clock by the Synchronome Company, a chronographic recorder reading to a quarter of a second, and a delicate galvanometer reading direct or in connection with a potentiometer. This installation, which has been made to specification by the Cambridge Scientific Instrument Co., has cost about 400*l.*, and is the most complete extant.

The melting-shop for non-ferrous metal will register the comparative melting efficiencies of coke, oil, gas, and electricity, each method being capable of making ingots of about 90 lb. weight. The static and dynamic testing of non-ferrous metals will be made in the ferrous department, which is provided with a single-lever Buckton machine on two centres, so that the machine may be arranged to read off the stress either in 3-in. ton moments or 12-in. ton moments. For more delicate work there is a two-ton static machine. The dynamic testing will be carried out on Arnold's standard stress-strain machine, on which it is hoped to obtain important results on the adherence of silverplating of different thicknesses on different basis metals.

In declaring the building open, Lord Haldane insisted most strongly that the industrial success of this country in the future depends upon the cordial cooperation of pure and applied science, which are practically indivisible. He said:—"Without a Kelvin or a Clerk Maxwell, or a Lister, or a man, to go further back, like Sir Isaac Newton, many of the things which we do to-day, and do so well, would not be done, but we have also to remember that unless other men of a similar type are produced in the future we cannot keep up to the level we are now at, but we should be at a disadvantage compared with other countries. You have done a very practical thing in founding this great new department of applied science; you have done the right thing in keeping applied science and pure science in close relation, and bringing both into intimate organic relation with the spirit of the University, that great permeating spirit without which they cannot be on a high level.

"What will be done in the department of applied science will be to go still further than has been possible in the past in bringing the application of science to bear on the problems of industry. It will not be practical work merely; it will be work in the course of which the student will be trained in the highest knowledge. He also will be told that he must not stop short at the conclusions to which science leads

him, but must show his capacity to apply the conclusions at which he has arrived to the actual and practical solution of the difficulties which confront the industrial world. In the old days pure science appeared to be something no one was interested in from the point of view of practical education. Now the greatest commercial discoveries depend upon new ideas, new conceptions being developed by men who have genius which makes them devoted to their work, even though they have to starve to do it. It is only in universities and technical schools that we find these men, and if British industry is to hold its own in the future, we shall have to realise the necessity there is, not only to turn to science, but to see that pure science has an opportunity of developing itself and being brought in contact with daily work."

Lord Haldane went on to contrast the rapid strides that are being made in the development of universities in America with what is being done in this country. He has, he said, great faith in the capacity of the British nation, but unless we wake up thoroughly in the matter of education, and particularly higher education, he is a little nervous as to what we may find the state of things concerning our industrial supremacy some fifteen or twenty years hence.

"Nowadays not only Governments, but Government Departments are waking up about these things. For the last twelve months there has been a great deal of activity about the business of national education. Mr. Pease is carrying out what I believe to be a right line of policy. He is trusting the very highly expert officials at the Board of Education and consulting the education committees throughout the country. The local education committees have done splendid work, but the burden on them has been very heavy. The nation will have to make up its mind to give considerably more out of the taxes for this work. The plans are now fashioned. The Government knows exactly what to do to make advance if only it has the nation at its back. I hate any idea of increasing expenditure, whether it is out of local or national resources, if it can be avoided. This expenditure, however, cannot be avoided. Unless we spend it we shall go back as a nation. Our revenues, by which we keep up our fleets and armies, will shrink, because we shall not be holding our own with the industrial nations. What Sheffield has done will have to be done right through the country."

Lord Haldane also referred to the report of the Advisory Committee on University Grants, and mentioned that this Committee, amongst other matters, has practically decided recently to deal with a pension fund for professors (see NATURE, March 6, 1913, p. 21), which, he said, "meant that instead of a man having to cling on to his post as the alternative to starving when he felt himself old, he could retire, and let a young man take his place, and go on with the development still further of the teaching which the professor had carried so far."

THE BRITISH ASSOCIATION AT BIRMINGHAM.

SECTION M.

AGRICULTURE.

OPENING ADDRESS BY PROF. T. B. WOOD, PRESIDENT
OF THE SECTION.

I PROPOSE to follow the example of my predecessor of last year, in that the remarks I wish to make to-day have to deal with the history of agriculture. Unlike Mr. Middleton, however, whose survey of the subject went back almost to prehistoric times, I pro-

pose to confine myself to the last quarter of a century—a period which covers what I may perhaps be permitted to call the revival of agricultural science.

Twenty-five years ago institutions concerned with the teaching of agriculture or the investigation of agricultural problems were few and far between. I do not propose to waste time in giving an exhaustive list, nor would such a list help me in developing the argument I wish to lay before the section. It will serve my purpose to mention that organised instruction in agriculture and the allied sciences was already at that date being given at the University of Edinburgh and at the Royal Agricultural College, whilst, in addition, one or more old endowments at other universities provided courses of lectures from time to time on subjects related to rural economy. Agricultural research had been in progress for fifty years at the Rothamsted Experimental Station, where the work of Lawes and Gilbert had settled for all time the fundamental principles of crop production. Investigations of a more practical nature had also been commenced by the leading agricultural societies and by more than one private landowner.

In these few sentences I have endeavoured to give a rough, but for my purpose sufficient, outline of the facilities for the study of agricultural science twenty-five years ago, at the time when the county councils were created. Their creation was followed almost immediately by what can only be called a stroke of luck for agriculture. The Chancellor of the Exchequer found himself with a considerable sum of money at his disposal, and this was voted by Parliament to the newly created county councils for the provision of technical instruction in agriculture and other industries.

Farmers were at that time struggling with the bad times following the wet seasons and low prices of the 'seventies and 'eighties, and some of the technical instruction grant was devoted to their assistance by the county councils, who provided technical instruction in agriculture. Thus, for the first time considerable sums provided by the Government were available for the furtherance of agricultural science; and, although at first there was no general plan of working and every county was a law unto itself, the result has been a great increase of facilities for agricultural education and research.

Almost every county has taken some part. The larger and richer counties have founded agricultural institutions of their own. In some cases groups of counties have joined together and federated themselves with established teaching institutions. For my purpose it suffices to state, without going into detail, that in practically every county, in one way or other, attempts have been made to carry out investigations of problems related to agriculture.

Twenty years after the voting of the technical instruction grant to the county councils, Parliament has again subsidised agriculture, in the shape of the Development Fund, by means of which large sums of money have been devoted to what may be broadly called agricultural science. It seems to me that the advent of this second subsidy is an occasion when this section may well pause to take stock of the results which have been achieved by the expenditure of the technical education grant. I do not propose to discuss the results achieved in the way of education, although most of the technical instruction grant has been spent in that direction. It will be more to the point in addressing the Agricultural Section to discuss the results obtained by research.

The subject, then, of my address is the result of the last twenty years of agricultural research, and I propose to discuss both successes and failures, in the

hope of arriving at conclusions which may be of use in the future.

Agricultural science embraces a variety of subjects. I propose to consider first the results which have been obtained by the numerous practical field experiments which have been carried out in almost every county. I suppose that the most striking result of these during the last twenty years is the demonstration that in certain cases phosphates are capable of making a very great increase in the crop of hay, and a still greater increase in the feeding value of pastures. This increase is not yielded in all cases, but the subject has been widely investigated, and the advisory staffs of the colleges are in a position to give inquirers trustworthy information as to the probability of success in almost any case which may be submitted to them. This is a satisfactory state of things, and the question naturally arises: How has it come about.

On looking through the figures of the numerous reports which have been published on this subject, it appears at once that in many cases the increase in live-weight of sheep fed on plots manured with a suitable dressing of phosphate has been twice as great as the increase in weight of similar animals fed on plots to which phosphate has not been applied. Now about a difference of this magnitude between two plots there can be no mistake. It has been shown by more than one experimenter that two plots treated similarly in every way are as likely as not to differ in production from their mean by 5 per cent. of their produce, and this may be taken as the probable error of a single plot. Where, as in the case of many of the phosphate experiments, a difference of 100 per cent. is recorded, a difference of twenty times the probable error, the chances amount to a certainty that the difference is not an accidental variation, but a real effect of the different treatment of the two plots. The single-plot method of conducting field trials, which is the one most commonly used, is evidently a satisfactory method of measuring the effects of manures which are capable of producing 100 per cent. increases. It was good enough to demonstrate with certainty the effects of phosphatic manuring on many kinds of grass land, and it is to this fact that we owe one of the most notable achievements of agricultural science in recent years.

Another notable achievement is the discovery that in the case of most of the large-cropping varieties of potatoes the use of seed from certain districts in Scotland or the northern counties of Ireland is profitable. This is another instance of an increase large enough to be measured accurately by the single-plot method. Reports on the subject show that seed brought recently from Scotland or Ireland gives increased yields of from 30 to 50 per cent. over the yields produced by seed grown locally for three or more years.

That the single-plot method fails to give definite results in many cases where it has been used for manurial trials is a matter of common knowledge. Half the reports of such trials consist of explanations of the discrepancies between the results obtained and the results which ought to have been obtained. The moral is obvious. The single-plot method, which suffices to demonstrate results as striking as those given by phosphates on some kinds of pasture land, signally fails when the subject of investigation is concerned with differences of 10 per cent. or thereabouts.

Before suggesting a remedy for this state of things it will be well to consider the allied subject of variety testing, which has been brought into great prominence recently by the introduction of new varieties of many

kinds of farm crops. In testing a new variety it is necessary to measure two properties—its quality and its yielding capacity—for money-return per acre is obviously determined by the product of yielding capacity and quality as expressed by market price. I propose here to deal only with the determination of yielding capacity. The determination of quality is not allied to manurial trials.

In attempting to determine yielding capacity there has always been a strong temptation to rely on the measurement of obvious structural characters. For instance, in the case of cereals many farmers like large ears, no doubt with the idea that they are an indication of high-yielding capacity. Many very elaborate series of selections have been carried out, on the assumption that large grains, or large ears, or many ears per plant implied high yield.

We may take it as definitely settled that none of these characters is trustworthy, and that the determination of yielding capacity resolves itself into the measurement of the yield given by a definite area. The actual measurement, therefore, is the same as that made in manurial trials, and is, of course, subject to the same probable error of about 5 per cent.

It follows, therefore, that it is subject to the same limitations. Variety trials on single plots, and that is the method commonly used, will serve to measure variations in yielding capacity of 30 per cent., or more, but are totally inadequate to distinguish between varieties the yielding capacities of which are within 10 per cent. of each other.

Numbers of such single-plot trials have been carried out, with the result that many varieties with yielding capacities much below normal have almost disappeared from cultivation, and those commonly grown do not differ greatly from one another—probably not more than 10 per cent.

Ten per cent. in yielding capacity, however, in cereals means a return of something like 15s. to 20s. per acre—a sum which may make the difference between profit and loss; and if progress is to be made in manuring and variety testing, some method must be adopted which is capable of measuring accurately differences in yield per unit area of the order of 10 per cent.

The only way of decreasing the probable error is to increase the number of plots, and to arrange them so that plots between which direct comparison is necessary are placed side by side, so as to reduce as much as possible variations due to differences in soil. Thus it has been shown that with ten plots in five pairs the probable error on the average can be reduced to about 1 per cent., in which case a difference of from 5 to 10 per cent. can be measured with considerable certainty.

Such a method involves, of course, a great deal of trouble; but agricultural science has now reached that stage of development at which the obvious facts which can be demonstrated without considerable effort have been demonstrated, and further knowledge can only be acquired by the expenditure of continually increasing effort. In fact, the law of diminishing return holds here, as elsewhere.

It appears, then, that for questions involving measurements of yield per unit area, such, for instance, as manurial or variety trials, further advance is not likely to be made without the expenditure of much more care than has been given to such work in the past. The question naturally arises: Is it worth while? I think the following instance shows that it is:—

Some years ago an extensive series of variety trials was carried out in Norfolk, in which several of the more popular varieties of barley were grown side by

side at several stations for several seasons. In all, the trial was repeated eleven times. As a final result it was found that Archer's stiff-straw barley gave 10 per cent. greater yield than any other variety included in the trials, and by repetition of the experiment the probable error was reduced to $1\frac{1}{2}$ per cent. The greater yield of 10 per cent., being over six times the probable error of the experiment, indicates practical certainty that Archer barley may be relied on to give a larger crop than any of the other varieties with which it was compared. One difficulty still remained. It was almost impossible to obtain anything like a pure strain of Archer barley. Samples of Archer sold for seed commonly contained 25 per cent. of other varieties. This difficulty was removed by Mr. Beaven, who selected, again with enormous trouble, a pure high-yielding strain of Archer barley. Since this strain was introduced into the Eastern Counties the demand for it has always exceeded the supply which could be grown at Cambridge and at the Norfolk Agricultural Station, and it is regarded by farmers generally as a very great success.

The conclusion, therefore, is that a 10 per cent. difference is well worth measuring, that it cannot be measured with certainty by the single-plot method, and that it behoves those of us who are concerned with field trials to look to our methods, and to avoid printing figures for single-plot experiments which may very well be misleading. Almost everyone thinks himself competent to criticise the farmer, who is commonly described as too self-satisfied to acquaint himself with new discoveries, and too conservative to try them when they are brought to his notice. Let us examine the real facts of the case. Does the farmer ignore new discoveries? The largely increasing practice of consulting the staffs of the agricultural colleges, which has arisen among farmers during the last few years, conclusively shows that he does not; that he is, in fact, perfectly ready to avail himself of sound advice whenever he can. Is he too conservative to try new discoveries when brought to his notice? The extraordinary demand for seed of the new Archer barley quoted above, and for seed of new varieties generally, the continuous advance in the prices of phosphatic manures, as the result of increased demand by farmers, the trade in Scotch and Irish seed potatoes, all show how ready the farmer is to try new things. The chief danger seems to be that he tries new things simply because they are new, and he may be disappointed if those who are responsible for the new things in question have not taken pains to ascertain with certainty that they are not only new but good. Farmers are nowadays in what may be called a very receptive condition. Witness the avidity with which they paid extravagant prices for single tubers of so-called new, but inadequately tested, varieties of potatoes some years ago, and in a less degree the extraordinary demand for seed of the much-boomed French wheats, and the excitement about nitragin for soil or seed inoculation. Witness, too, the almost universal failure of the new potatoes and French wheats introduced during the boom, and the few cases in which nitragin gave any appreciable result. The farmer who was disappointed with his ten-guinea tuber, his expensive French wheat, or his culture of nitragin cannot but be disillusioned. Once bitten, twice shy. He does not readily take advice again.

Let us, therefore, recognise that the farmers of the country are ready to listen to us, and to try our recommendations, and let that very fact bring home to us a sense of our responsibility. All that is new is not, therefore, necessarily good. Before we recommend a new thing let us take pains to assure ourselves of its goodness. To do so we must find not only that

the new thing produces a greater return per acre, but that the increased return is worth more than it costs to produce, and we must also define the area or the type of soil to which this result is applicable. This implies in practice that each field trial should confine itself to the investigation of only one, or, at most, two, definite points, since five pairs of plots will be required to settle each point; that the experimental results should be reviewed in the light of a thorough knowledge of farm book-keeping, and that accurate notes should be taken of the type of the soil, and the area to which it extends, and of the various meteorological factors which make up the local climate. At present we are not in possession of a sufficient knowledge of farm accountancy, but there is hope that this deficiency will be removed by the work of the Institute for Research in Agricultural Economics, which has recently been founded at Oxford by the Board of Agriculture and the Development Commission. The excellent example set by Hall and Russell in their "Survey of the Soils and Agriculture of the South-Eastern Counties," an example which is being followed in Cambridge and elsewhere, seems likely to result in the near future in a complete survey of the soils of England which will make a sound scientific basis for delimiting the areas over which the results of manurial or variety trials are applicable.

Reviewing this branch of agricultural science, the outlook is distinctly hopeful. New fertilisers are coming into the market, as, for instance, the various products made from atmospheric nitrogen. New varieties of farm crops are being produced by the Plant-breeding Institute at Cambridge, and elsewhere. It is to be hoped that the work of the Agricultural Economics Institute at Oxford will throw new light on the interpretation of experimental results from the accountancy standpoint. Finally, the soil surveys on which the colleges have seriously embarked will assist in defining the areas over which such results are applicable. It only remains for those of us who are responsible for the conduct of field trials to increase the accuracy of our results, and the steady accumulation of a mass of systematic and scientific knowledge is assured. It will be the business of the advisory staffs with which the colleges have recently been equipped by the Board of Agriculture and the Development Commission to disseminate this knowledge in practicable form to the farmers of this country.

One more point, and I have finished this section of my address. I have perhaps inveighed rather strongly against the publication of the results of single-plot trials. I quite recognise that the publication of such results was to a great extent forced upon those experimenters who were financed by annually renewed grants of public money. Nowadays, however, agricultural science is in a stronger position, and I venture to hope that most public authorities which subsidise such work are sufficiently alive to the evils attendant on the publication of inconclusive results to agree to continue their grants for such periods as may suffice for the complete working out of the problem under investigation, and to allow the final conclusions to be published in some properly accredited agricultural journal, where they would be readily and permanently available to all concerned. This would in no wise prevent their subsequent incorporation in bulletins specially written for the use of the practical farmer.

So far I have confined my remarks to subjects of which I presume that every member of the section has practical experience, subjects which depend on the measurement of the yield per unit area. These subjects, however, although they have received far more general attention than anything else, by no means comprise the whole of agricultural science. Certain

scientific workers have confined their efforts to the thorough solution of specific and circumscribed problems. I propose now to ask the section to direct its attention to some typical results which have been thus achieved during the last twenty years.

The first of these is the development of what I may call soil science. Twenty years ago the bacteriology of nitrification had just been worked out by Warington and by Winogradski. The phenomena of ammoniacal fermentation of organic matter in the soil were also fairly well established. The fixation of atmospheric nitrogen by organisms symbiotic on the leguminosæ had been definitely demonstrated. Fixation of nitrogen by free-living organisms had been suggested, but was still strenuously denied by most soil investigators. No suggestion had yet been made of the presence in normal soils of any factor which inhibited crop production. The last twenty years have seen a wonderful advance in soil science. Our knowledge of nitrification and ammoniacal fermentation has been much extended. The part played by the nodule organisms of the leguminosæ has been well worked out, has seen a newspaper boom, and a subsequent collapse, from which it has not yet recovered. But the greatest advance has been the discovery of the part played by protozoa in the inhibition of fertility.

The suggestion that ordinary soils contained a factor which limited their fertility emanated in the first instance from the American Bureau of Soils. The factor was at first thought to be chemical, and its presence was tentatively attributed to root excretion. Certain organic substances, presumably having this origin, have been isolated from sterile soils, and found to retard plant growth in water-culture. It is claimed, too, that the retardation they cause is prevented by the presence of many ordinary manurial salts with which they are supposed to form some kind of combination.

Contributions to the subject have come from several quarters, but whilst the suggested presence of an inhibitory factor has been generally confirmed, its origin as a root-excretion and its prevention by manurial salts has not received general confirmation outside American official circles. The matter has been strikingly cleared up by the work of Russell and Hutchinson at Rothamsted, who observed that the fertility of certain soils which had become sterile was at once restored by partial sterilisation, either by heating to a temperature below 100° C., or by the use of volatile antiseptics such as toluene. This observation suggested that the factor causing sterility in these cases was biological in nature, that it consisted, in fact, of some kind of organism inimical to the useful fermentation bacteria, and more easily killed than they by heat or antiseptics. After a long series of admirable scientific investigations these workers and their colleagues have shown that soils contain many species of protozoa, which prey upon the soil bacteria, whose numbers they keep within definite limits. In certain circumstances, such, for instance, as those existing in the soil of sewage farms, and in the artificial soils used for the cultivation of cucumbers, tomatoes, &c., under glass, the protozoa increase so that the bacteria are reduced below the numbers requisite to decompose the organic matter in the soil into substances suitable for absorption by the roots of the crop. Practical trials of heating such soils, or subjecting them to the action of toluene, or other volatile antiseptics, have shown that their lost efficiency can thus be easily restored, and the method is now rapidly spreading among the market gardeners of the Lea Valley.

I have attempted to sketch the chief points of this

subject with some detail in order to show that strictly scientific work, quite outside the scope of what some people still regard as "practical," may result in discoveries which, apart from their great academic interest, may at once be turned to account by the cultivator. The constant renewal of expensively prepared soil which becomes "sick" in the course of a year or so is a serious item in the cost of growing cucumbers and tomatoes. It can now be restored to fertility by partial sterilisation at a fraction of the cost of renewal, and considerable sums are thus saved by the Lea Valley growers.

For my second instance of scientific work which has given results of direct value to farmers, I must ask to be allowed to give a short outline of the wheat-breeding investigations of my colleague Prof. Biffen. Even as late as fifteen years ago plant-breeding was in the purely empirical haphazard stage. Then came the rediscovery of Mendel's laws of heredity, which put in the hands of breeders an entirely new weapon. About the same time the Millers' Association created the Home-grown Wheat Committee, of which Biffen was a member. Through this committee he was able to define his problem as far as the improvement of English wheat was concerned. There appeared to be two desiderata: (1) The production of a wheat which would crop as well as the best standard home-grown varieties, at the same time yielding strong grain, *i.e.* grain of good milling and baking quality; and (2) the production of varieties of wheat resistant to yellow rust, a disease which has been computed to decrease the wheat crop of the world by about one-third.

The problem having been defined, samples of wheat were collected from every part of the world and sown on small plots. From the first year's crop single ears were picked out and grown on again. Thus several hundred pure strains were obtained. Many were obviously worthless. A few possessed one or more valuable characteristics: strong grain, freedom from rust, sturdy straw, and so on. These were used as parents for crossing, and from the progeny two new varieties have been grown on, thoroughly tested, and finally put on the market. Both have succeeded, but both have their limitations. Burgoyne's Fife, which came from a cross between strains isolated respectively from Canadian Red Fife and Rough Chaff, was distributed by the Millers' Association after a series of about forty tests, in which it gave an average crop of forty bushels per acre of grain, which milled and baked practically as well as the best imported Canadian wheat. It is an early-ripening variety which may even be sown as a spring wheat. It has repeatedly been awarded prizes for the best sample of wheat at shows, but it only succeeds in certain districts. It is widely and successfully grown in Bedfordshire and Dorset, but has not done well in Norfolk. The other variety, Little Joss, succeeds much more generally. In a series of twenty-nine trials scattered between Norfolk and Shropshire, Kent and Scotland, it gave an average of forty-four bushels per acre, as compared with forty bushels given by adjoining plots of Square Head's Master. It originated from a cross between Square Head's Master and a strain isolated from a Russian graded wheat known as Ghirka. Its grain is the quality of ordinary English wheat. It tillers exceptionally well in spring, and is practically rust-proof. Its one drawback is its slow growth during the winter if sown at all late. It has met with its greatest success in the Fen districts, where rust is more than usually virulent.

The importance of this work is not to be measured only by the readiness with which the seed of the new varieties has been tried by farmers and the extent to

which it has succeeded. The demonstration of the inheritance of immunity to the disease known as yellow rust, the first really accurate contribution to the inheritance of resistance to any kind of disease, inspires hope that a new method has appeared for the prevention of diseases in general.

Biffen's work too shows the enormous value of co-operation between the investigator and the buyer in defining problems connected with the improvement of agricultural produce. It is open to doubt if a committee of farmers would have been able to define the problems of English wheat production as was done by the Millers' Committee, and in the solution of any problem its exact definition is half the battle. Mackenzie and Marshall in their work on the "Pigmentation of Bacon Fat" and on the spaying of sows for fattening, have found the great value of consultation with the staffs of several large bacon factories. There seems to be in this a general lesson that before taking up any problem one should get into touch not only with the producers but with the buyers, from whom much useful information can be obtained.

I feel that Biffen's work has borne fruit in still another direction, for which perhaps he is not alone responsible. Twenty years ago agricultural botany took a very subsidiary position in such agricultural examinations as then existed. In some of the agricultural teaching institutions there was no botanist, in others the botanist was only a junior assistant. It is largely due to the work of Biffen and the botanists at other agricultural centres that botany is now regarded as perhaps the most important science allied to agriculture.

I must here repeat that I am not attempting to make a complete survey of all the results obtained in the last twenty years. My object is only to pick out some of the typical successes and failures and to endeavour to draw from their consideration useful lessons for the future. So far I have not referred to the work which has been done in the nutrition of animals, and I now propose to conclude with a short discussion of that subject. The work on that subject which has been carried out in Great Britain during the last twenty years has been almost entirely confined to practical feeding trials of various foods or mixtures of foods, trials which have been for the most part inconclusive.

It has been shown recently that if a number of animals in store condition are put on a fattening diet, at the end of a feeding period of twelve to twenty weeks about half of them will show live-weight increases differing by about 14 per cent. from the average live-weight increase of the whole lot. In other words, the probable error of the live-weight increase of a single fattening ox or sheep is 14 per cent. of the live-weight increase. This being so, it is obvious that very large numbers of animals must be employed in any feeding experiment which is designed to compare the feeding value of two rations with reasonable accuracy. For instance, to measure a difference of 10 per cent. it is necessary to reduce the probable error to 3 per cent. in order that the 10 per cent. difference may have a certainty of thirty to one. To achieve this, twenty-five animals must be fed on each ration. Those conversant with the numerous reports of feeding trials which have been published in the last twenty years will agree that in very few cases have such numbers been used. We must admit then that many of the feeding trials which have been carried out can lay no claim to accuracy. Nevertheless, they have served a very useful purpose. From time to time new articles of food come on the market, and are viewed with suspicion by the farmers. These have been included in

feeding trials and found to be safe or otherwise, a piece of most useful information. Thus, for instance, Bombay cotton cake, when first put on the market, was thought to be dangerous on account of its woolly appearance. It was tried, however, by several of the agricultural colleges and found to be quite harmless to cattle. Its composition is practically the same as that of Egyptian cotton cake, and it now makes on the market practically the same price.

Soya-bean cake is another instance of a new food which has been similarly tested, and found to be safe for cattle if used in rather small quantities and mixed with cotton cake. The price is now rapidly rising to that indicated by its analysis. Work of this kind is, and always will be, most useful. Trials with few animals, whilst they cannot measure accurately the feeding value of a new food, are quite good enough to demonstrate its general properties, and its price will then gradually settle itself as the food gets known.

Turning to the more strictly scientific aspects of animal nutrition, entirely new ideas have arisen during the last twenty years. I propose to discuss these shortly, beginning with the proteins. Twenty years ago the generally accepted view of the rôle of proteins in nutrition was that the proteins ingested were transformed in the stomach and gut into peptones, and absorbed as such without further change. Splitting into crystalline products, such as leucin and tyrosin, was thought only to take place when the supply of ingested protein exceeded the demand, and peptones remained in the gut for some time unabsorbed. It is now generally agreed that ingested protein is normally split into crystalline products which are separately absorbed from the gut, and built up again into the various proteins required by the animal. If the ingested protein does not yield a mixture of crystalline products in the right proportions to build up the proteins required, those crystalline products which are in excess are further changed and excreted. If the mixture contains none of one of the products required by the animal, then life cannot be maintained. This has been actually demonstrated in the case of zein, one of the proteins of maize, which contains no tryptophane. The addition of a trace of tryptophane to a diet, in which zein was the only protein, markedly increased the survival period of mice.

The adoption of this view emphasises the importance of a knowledge of the composition of the proteins, and especially of a quantitative knowledge of their splitting products, and much work is being directed to this subject in Germany, in America, and more recently in Cambridge as a result of the creation there of an institute for research in animal nutrition by the Board of Agriculture and the Development Commission. This work is expected ultimately to provide a scientific basis for the compounding of rations, the idea being to combine foods the proteins of which are, so to speak, complementary to each other, one giving on digestion much of the products of which the other gives little. Meantime, it is desirable that information should be collected as to mixtures of foods which are particularly successful or the reverse.

Here the question arises, for what purpose does the animal require a peculiarly complicated substance like tryptophane? The natural suggestion seems to be that the tryptophane grouping is required for the building up of animal proteins. It has also been suggested that such substances are required for the formation of hormones, the active principles of the internal secretions the importance of which in the animal economy has received such ample demonstration in recent years. The importance of even mere traces of various substances in the animal economy is another quite recent conception. Thus it has been

shown, both in Cambridge and in America, that young animals fail to grow on a diet of carefully purified casein, starch, fat, and ash, although they will remain alive for long periods. In animals on such a diet, however, normal growth is at once started by the addition of a few drops of milk or meat juice, or a trace of yeast, or other fresh animal or vegetable matter. The amount added is far too small to affect the actual nutritive value of the diet. Its effect can only be due to the presence of a trace of some substance which acts, so to speak, as the hormone of growth. The search for such a substance is now being actively prosecuted. Its discovery will be of the greatest scientific and practical interest.

Evidently new ideas are not lacking amongst those who are engaged in investigating the rôle of the proteins and their splitting products in the animal economy. But of more immediate practical interest is the question of the amount of protein required by animals under various conditions. It is obviously impossible to fix this amount with any great accuracy, since proteins differ so widely in composition, but from many experiments, in which a nitrogen balance between the ingesta and the excreta was made, it appears that oxen remain in nitrogenous equilibrium on a ration containing about one pound of protein per 1000 lb. live-weight per day. All the British experiments of a more practical nature have been recalculated on a systematic basis by Ingle, and tabulated in the Journal of the Highland and Agricultural Society. From them it appears that increase of protein in the ration, beyond somewhere between one and a half and two pounds per 1000 lb. live-weight per day of digestible protein, ceases to have any direct influence on increase in live-weight.

We may fairly conclude, then that about two pounds of proteins per 1000 lb. live-weight per day is sufficient for a fattening ox. This amount is repeatedly exceeded in most of the districts where beef production is a staple industry, the idea being to produce farmyard manure rich in nitrogen. The economy of this method of augmenting the fertility of the land is very doubtful. The question is one of those for the solution of which a combination of accurate experiment and modern accountancy is required. Protein is the most expensive constituent of an animal's dietary. If the scientific investigator, from a study of the quantitative composition of the proteins of the common farm foods, and the economist, from careful dissection of farm accounts, can fix an authoritative standard for the amounts of protein required per 1000 lb. live-weight per day for various types of animals, a great step will have been made towards making mutton and beef production profitable apart from corn-growing.

For many years it has been recognised that an animal requires not only so much protein per day, but a certain quota of energy, and many attempts have been made to express this fact in intelligible terms. Most of them have taken as basis the expression of the value of all the constituents of the diet in terms of starch, the sum of all the values being called the starch equivalent. This term is used by various writers in so many different senses that confusion has often arisen, and this has militated against its general acceptance. Perhaps the most usual sense in which the term is used is that in which it means the sum of the digestible protein multiplied by a factor (usually 94) plus the digestible fat multiplied by a factor (usually 2.3), plus the digestible carbohydrates. This, however, gives misleading values which are too high in concentrated foods and too low in bulky foods, the discrepancy being due to the larger proportion of the energy of the bulky foods which is used up in the much greater work of digestion which

they require. Kellner and his school have devised a method which measures the starch equivalent by experiment, a much more satisfactory and practical method than any system which depends purely on calculation.

An animal or a number of animals are kept on a maintenance diet so that their weight remains constant. To this diet is added a known weight of starch, and the increase in weight observed. The animal or animals are then placed again on the same maintenance diet for some time, and then a known weight of the food to be tested is added, and the increase in weight again observed. The data thus obtained indicate that so many pounds of starch produce as much increase in live-weight as so many pounds of the food under experiment, from which it is easy to calculate how many pounds of starch are actually required to produce as much increase in live-weight as 100 lb. of the food under experiment. The starch equivalent thus found expresses an experimentally determined fact which is of immediate practical value in arranging a dietary, its value, however, depending on the accuracy with which it has been determined. Kellner and his colleagues have thus determined the starch equivalents of all the commonly used foods. Their values for concentrated foods, and other foods commonly used in Germany, have been determined with considerable accuracy, and with the method which has also been devised for defining the relation between the experimentally determined equivalent and the equivalent calculated from the analysis by means of a formula, they form by far the most trustworthy basis for arranging a feeding ration including such kinds of foods.

But roots, which form the staple of the diet of fattening animals in Great Britain, are not used on the same scale in Germany, and Kellner's starch equivalents for roots have not been determined with sufficient accuracy or under suitable conditions to warrant their use for arranging diets under our conditions.

This, and the fact that the term starch equivalent is so widely misunderstood, is no doubt the reason why the Kellner equivalent has not been more generally accepted in Great Britain. An advance will be made in the practice of feeding as soon as the starch equivalent of roots has been accurately determined under our conditions, when the Kellner equivalents will no doubt come into general use.

I have now reached the end of my survey. I recognise that it is very incomplete, and that I have been compelled to neglect whole subjects in which important work has been done. I venture to hope, however, that my words have not been altogether unprofitable. It is somewhat difficult to summarise what is in itself really nothing but a summary. Perhaps, however, I may be allowed to point out once more what appears to me to be the moral of the last twenty years of work in agricultural science.

The many practical field and feeding tests carried out all over the country have demonstrated several very striking results; but, if they are to be continued with profit, more trouble must be taken to insure accuracy. Farmers are ready to listen. It behoves us more than ever to found what we tell them on accurate results.

Besides such practical trials, however, much has been done in the way of individual scientific work. The results thus obtained, as, for instance, Russell and Hutchinson's partial sterilisation of soils, Biffen's new wheats, and Beaven's pure Archer barley, are of practical value to the farmer as immediate as the most practical field trial, and of far wider application.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—The Herbert Spencer lecture will be delivered by Prof. C. Lloyd Morgan, F.R.S., professor of psychology in the University of Bristol, on Friday, November 7. The subject of the lecture will be:—"Spencer's Philosophy of Science."

DR. O. W. RICHARDSON, F.R.S., professor of physics in Princeton University, New Jersey, has been appointed as from January 1 next to the Wheatstone chair of physics at King's College, London, in succession to Prof. C. G. Barkla, F.R.S.

MRS. W. BAYARD CUTTING and her children have (says *Science*) given 40,000l. to Columbia University for a fund in memory of the late W. Bayard Cutting, who served as trustee of the University from 1880 until his death, in 1912. The income of this fund is to be applied to the maintenance of travelling fellowships, open to graduate students of distinction in letters, science, law, and medicine or engineering.

STUDENTS who are working privately with the object of graduating in the University of London will welcome the "London University Guide and University Correspondence College Calendar, 1914," published by the University Correspondence College, London, and distributed gratuitously. The first part of the volume constitutes the guide, and contains the regulations for the examinations leading to the various degrees to be held by the University of London in 1914 and 1915. The calendar, 1913-14, which completes the volume, gives particulars of the facilities offered by the University Correspondence College to students who desire assistance in their work through the post.

A VERY useful form of pocket diary, which covers the academic year beginning with October, 1913, instead of commencing with January in the usual way, has been published by the Cambridge University Press. Though concerned more particularly with events in the work of the University of Cambridge, the diary will appeal to all whose work is in connection with colleges or schools. The diary is published in three forms, at 1s. net, 2s. net, and 2s. 6d. net respectively. From the same source we have received "The Cambridge Diary for the Academic Year 1913-14," in block form. Each sheet contains seven days, and ample space is provided for manuscript notes of engagements. The price of this diary is 1s. net.

THE establishment of new universities in Germany was one of the chief topics of discussion at the recent congress of German university teachers held at Strasbourg. The movement was strongly opposed in a report presented by Prof. Bücher, of Leipzig. According to this, many corporations, with the encouragement of the Ministry are endeavouring to raise the status of existing institutions to that of university rank. The preponderance of government in such institutions would be municipal, and consequently university independence would be endangered, and, in addition, a high academic standard would not be maintained. Overcrowding of the existing universities was advanced as an argument in favour of the creation of new institutions, but the organisation of such universities as those of Berlin and Leipzig enabled them to deal with large numbers without any detriment to the teaching. Prof. Kaufmann, of Breslau, remarked that quite 40 per cent. of the students were unsuited for an academic training, and the creation of new institutions would in no way relieve overcrowding at the older universities, but simply increase