Britain. The grid now practically joins up all the 'effective' generating stations. The overhead lines are roughly parallel to many of the main railways.

The Southern Railway inherited from the London, Brighton and South Coast Railway a very flourishing suburban electrified system. Had not the grouping altered matters, it was the intention of the directors not only to finish the electrification of all their suburban systems, but also to work electrically the whole of the main lines as far as Worthing, Brighton, Eastbourne, and Hastings. Taking into account the fact that most of the lines were actuated by direct current, the Southern Railway adopted the d.c. system as the standard. It is still engaged in electrifying the passenger lines from London to Brighton and Worthing on this system. Its electrical lines at present are equivalent to about 750 miles of single track, besides the mileage required for side tracks, garaging purposes, etc. It possesses no electric locomotives, using 881 electrified motor carriages. Only a few miles of the Great Western Railway are electrified. The London, Midland and Scottish Railway has electrified the lines between Liverpool and Southport, Lancaster and Morecambe Bay, and Old Broad Street to Watford. The London and North Eastern Railway has only electrified a suburban section at Newcastle and a goods line in the neighbourhood of Sunderland, from Newport to Shildon. On the Newport line, electric locomotives are used. There are also several lines of purely local interest such as the Underground Railways of London.

The Weir Commission was appointed by the last Government to examine the economic and other aspects of the problem of electrifying the main railway lines of Great Britain. The report was published in March of last year, and confirmed the views of those engineers who held that electrification would lead to important economies and would be a boon to the country. The working results obtained by several electric railways in other countries also support this conclusion. In France particularly the electrification of the main lines has been very beneficial. It is pointed out that although Great Britain was the pioneer of steam railways it lags behind several other countries in electrifying its railways.

Sir Philip Dawson has made special studies of the main lines of the London, Brighton and South Coast Railway and of a project for electrifying the greater part of the main lines of the Great Western Railway. He finds that for slow goods trains the mean velocity is increased 30 per cent by using electric traction, and that for ordinary passenger trains the mean speed can be increased 25 per cent. The cost of repairs, renewals, and upkeep of locomotives is approximately 40 per cent of that of steam railways. This agrees closely with the estimates made by other engineers. Adding together the total capital required for electrifying all the railways in Great Britain, the economies directly attributable to this change would show a gain of 7-10 per cent upon the capital employed.

The quantity of energy necessary to supply a railway depends on local conditions and on the 'ton miles' required by different kinds of trains. A rough estimate can be made of the cost by examining the corresponding costs of electric railways abroad. Taking this as a basis and assuming the average cost of the ton mile on British railways, it is estimated that the 'maximum demand' for direct current from the railway substations would be of the order of 1·5 million kilowatts. To get the average load the mean factor is assumed to be 0·5. Hence the annual consumption on the d.c. side of the railway substations would be about 6500 million kilowatt hours a year.

If the electrification of the railways of Great Britain were begun at once, it would be finished by 1950. Assuming that the expected load on the 'grid' at that date is realised, the demand of the railways would be a fifth of the total output from the grid. The maximum of the railway demand from the grid would be about ten per cent of the total demand. To convert the standard three-phase a.c. supply into direct current, mercury rectifiers would probably be employed. Assuming that this is done, the efficiency of the conversion would be 84 per cent. Estimating that the cost of a kilowatt hour at the generating station would be 0·25*d.*, the cost for the d.c. unit supplied to the railway would be 0·495*d.* This compares excellently with the 0·5*d.* unit given in the Weir Report. Adding on the cost of operating the substations, we find that the total cost would be 0·55*d.*

The regular supply of energy taken by the electrified railways from the grid would react most favourably by lowering the general price of electricity. The electrification would necessitate the construction of about ten new power stations, for which the cost would be appreciably less than that of existing stations, thus contributing to the general lowering of the price of electricity. The necessary great increase in the number of substations would make it possible to supply electricity economically for general purposes to new areas. It will be seen that the conclusions Sir Philip Dawson draws will encourage railway engineers to proceed with their electrification schemes.

Obituary

PROF. GRAHAM LUSK, FOR.MEM.R.S.

AN investigator whose enthusiasm in the pursuit of knowledge never waned; a man who never wavered from the high standards of work and conduct which he set for himself in youth, and whose qualities of mind and heart endeared him to all; a teacher who always gave of his best: such was Graham Lusk. As such he will be greatly missed in many centres by a multitude of colleagues, friends, and pupils. From the beginning of his adult life to its end—for more than forty years—he devoted himself to the study of the problems of animal metabolism and nutrition. His first paper, published in 1889, dealt with human diabetes, and his last, in 1931, was concerned with the influence of the thyroid upon phloridzin diabetes in the dog. Lusk himself found pleasure in remembering that in 1871 a paper of his father's upon diabetes was published, so that in each decennium for sixty years articles on that subject bore the family name.

Graham Lusk was born at Bridgeport, Connecticut, on Feb. 15, 1866. His father, W. T. Lusk, was a physician of high professional and social standing, who before and after the American Civil War, in which he took part, studied at many European centres. On his advice his son refrained from taking a medical degree, as the deafness from which the latter suffered, then and always, would have made professional practice difficult.

The elder Lusk had a firm belief in the importance of chemistry to physiology and medicine, and Graham therefore went to Germany to obtain, as he himself has said, a sufficient knowledge of physiological chemistry to give him a broader background than that possessed by the medical chemists of the day. At the age of twenty-one years he went to Munich to work under Carl Voit, but found that he could not at once enter the research laboratory. He had first to spend a year in listening to Voit's lectures and in attending so-called practical classes, in which students stood for two hours watching the professor perform experiments. After this probation he was allowed to join the research community, and from the first made a good impression upon Prof. Voit and his staff. The first product of his work was the paper on diabetes already mentioned.

Lusk acquired great affection for Voit, and never failed to speak and write of him with praise and gratitude. He displayed equal loyalty to his other great teacher, Max Rubner, with whom he continued a lifelong friendship.

Lusk's own work, carried out first at Yale and then for more than thirty years at Cornell Medical College, where he held the chair of physiology, reflected the influence of the two teachers he so much admired. It combined the methods that each of these in turn had developed for the study of metabolism: Voit's chemical technique and Rubner's appeal to calorimetry. Lusk's employment of the latter came for the most part after the first classical experiments of his American *confrères*, Atwater and Benedict, had been done; but while these were mainly concerned with the energy balance-sheet of human metabolism, Lusk used the calorimeter rather as a control for chemical studies.

Lusk explored very many aspects of metabolism. Among his special interests were the fate of ingested carbohydrates and the sources of endogenous sugar. His first work under Voit had brought evidence against the then current contention of Pflüger that sugar could not arise in the body from protein. In the early 'nineties, controversy on this point was so bitter in Germany that Voit was astonished to hear that Pflüger had consented to speak to the young author of the work in question! It fell to Lusk in later years not only to supply some of the evidence which finally compelled the conversion of Pflüger, but also to give precision to our knowledge of this incident in metabolism by determining with exactness the maximal amount of sugar which each individual amino acid from protein can yield in the animal body. This he did by administering known amounts of each to phloridzinised dogs and estimating the extra sugar which the animal excreted in consequence. He made indeed, during the course of several years, an intensive study of phloridzin diabetes, and thereby acquired important information concerning various aspects of metabolism.

An aspect which long interested Lusk was that which Rubner had termed the 'specific dynamic action' of foodstuffs. As is now so well known, the consumption of food, but especially the consumption of protein, increases *per se* the heat output of the resting body. If what we now call the basal metabolism of a typical animal be taken as 100 calories per day, and if these 100 calories be administered to the animal in the form of each of the several foodstuffs on different days, then the heat production of the still resting animal after receiving meat protein will rise to about 130 calories, after glucose to about 106 calories, and after fat to about 104 calories. These, according to Lusk, are typical average results. Rubner's explanation of the high figure for protein was that the extra heat corresponded to the free heat of certain thermal chemical reactions in *intermediary* metabolism, probably localised in the liver and representing energy not available for muscular or general tissue activity. Protein differs from carbohydrate and fat in that, whatever the current nutritional needs, the products of its digestion promptly undergo change in the body; a fact demonstrated by an immediate rise in the excretion of nitrogen. Unlike fat or carbohydrate, protein when administered in excess of contemporary needs is not stored as such, but only that moiety is stored which is capable of yielding sugar and therefore glycogen. In any event, the nitrogen of its products is removed before they serve as a source of utilisable energy. Such preliminary reactions thus give origin to that output of heat which is independent of activity.

Such was Rubner's view, and Lusk set himself to obtain experimental evidence in support of it. Unexpected results, however, led him to hold for a time a quite different view of his own. He studied the specific dynamic action (in Rubner's sense) of individual amino acids from protein, and established the interesting fact that while the administration of some among them causes a marked increase on the output of heat from the body, others have no such effect. Rubner, rather over-simplifying a statement of his views, had suggested that the extra heat of protein administration might be considered to come from the direct oxidation of that part of its molecule which is incapable of conversion into sugar. Lusk thought he had disproved this. Glycin and alanine, for example, he found to exert a marked specific dynamic action, while (as could be demonstrated in the phloridzinised animal) they can nevertheless, after de-amination, be wholly converted into sugar. On the other hand, glutamic acid exerts no dynamic action whatever, and yet only three out of its five carbon atoms appear in its yield of sugar. Such results as these, together with other experimental evidence, led Lusk to believe that the extra heat output which follows on protein consumption is due to a direct stimulation of general tissue activity. The stimulus is due to certain constituent amino acids or to certain primary products of their breakdown.

Such a view, if confirmed, would have justified the term ' specific dynamic action ' better than the conceptions of its originator. Nevertheless, further work by Lusk himself, and some by others, has rendered the view untenable. Other explanations have been since advanced, but none seems entirely satisfactory. It is probable that the contributory happenings are complex, and that we at present lack sufficient knowledge of the chemical details of intermediary metabolism for full understanding of the phenomenon in question.

I have dwelt upon Lusk's dealings with this elusive problem because it was one which greatly interested him, and his study of it well illustrates his method of applying calorimetry to matters of detail. He never had any difficulty about giving up a theory of his when it ceased to account for facts. He said it cheered him to remember Marat's characterisation of Lavoisier, " a charlatan . . . who changes his theories as he does his shoes ". In successive editions of his book he is always frank in admitting a personal change of view, and in the last he deals faithfully with all the evidence bearing upon the nature of specific dynamic action so called. This book, the " Elements of the Science of Nutrition ", of which the fourth and last edition was published in 1928, is encyclopædic in its dealings with the literature. It lacks perhaps logical sequence in presentation, and the relative value of conflicting evidence is sometimes left unappraised; but it is written without bias, and contains abundant suggestions which have stimulated research in many quarters.

Lusk was too gentle to be a severe critic, but he was capable of intense indignation upon adequate cause. Certain opinions concerning aspects of metabolism he held with extreme firmness. He would not, for example, admit that fat could be converted into sugar in the body, and refused to believe that sugar is the sole immediate source of energy for muscular activity.

It will be recalled that, together with R. H. Chittenden, Lusk represented America on the Inter-Allied Scientific Food Commission in 1917. He frequently visited Great Britain, where he and Mrs. Lusk had many friends. Shortly before his death, on July 18, he expressed his deep appreciation of his election to the foreign membership of the Royal Society, and the Society itself will be always glad that the honour was offered in time to give him that pleasure.

F. G. H.

SIR WILLIAM WILLCOCKS, K.C.M.G.

WITH the death of Sir William Willcocks, on July 28, there passed out of the engineering world and Egyptian everyday life one of the original band of engineers who helped to rescue that country from the financial bankruptcy into which it had been led by Ismail Pasha. Born in India in 1852, Willcocks passed brilliantly through the Thomason Engineering College, Roorkee, and gained his first irrigation experience in that country during eleven years' service with the Irrigation Department of the United Provinces.

Willcocks was brought to Egypt in 1883 by Sir Colin Scott Moncrieff, and at once devoted himself to the reorganisation of the irrigation system on which that country's prosperity almost entirely depends. On arrival he was given charge of the provinces of Gharbieh and Menoufieh, which lie in the Delta between the two branches of the Nile and are among the richest of the provinces. He immediately realised the urgent necessity for the construction of regulating works at the heads of canals so as better to regulate their flow and at the same time reduce the enormous silt deposits which not only impaired their efficiency but also called for intensive work of clearing by the forced labour system known as the ' corvee '. It was not long before this imposition, which had annually compelled 230,000 men out of a total population of 6,000,000 souls to work for about 170 days without pay, was abolished.

Willcocks' district then covered an area of some two million acres. With characteristic energy he used to tramp all over the country on foot, and soon became a familiar figure and almost a household word with the ' fellaheen '.

It was on account of his resourcefulness and courage that Willcocks was entrusted with the diagnosis of the ' disease ' which, since their completion in 1861, had beset the two barrages, or dams, which Mougel Bey had designed and built at the heads of the Rosetta and Damietta branches of the Nile. Before they had been repaired, he courageously used them for raising the water level so as to give the canals a more plentiful supply. This was achieved by throwing a bank of loose rubble across the bed of the Rosetta barrage, thereby reducing the pressure of water which it had to bear, and, although signs of weakness did develop, the country profited for that season. The reconditioning of the barrages then followed. He was responsible for the remodelling of many canals and their attendant regulating works.

Having done so much to improve the system by which water is distributed, Willcocks was asked to devise a scheme for supplementing the supply of water at seasons when the natural flow of the Nile is deficient. His surveys of Nubia which resulted from this campaign, and his measurements of the flow of the Nile, find their parallel in the work done by the ' savants ' of the Napoleonic expedition. The principles which he enunciated were those finally adopted in developing the Assuan reservoir scheme, which has up to the present day been