

morphology), have until now had no completely solid theoretical basis. However, they can be used as semi-empirical methods, and viscosity, from this point of view, is quite useful because of its very simple experimental device. In the present state of affairs, there can be little doubt that the light-scattering method is the most reliable, both from the theoretical and experimental points of view. Its generalization to the use of small wave-lengths (for example, X-rays) makes it useful even to the lower limit of the macromolecular domain.

Though it may be felt that the work leading to a complete description of a chain macromolecule—including its morphology—does not need any further justification, it is nevertheless useful to indicate a few aspects of its consequences. Nobody, in fact, doubts the necessity of inquiring about the molecular weight and the short-range structure of a chain, since these factors are of first-rate importance with regard to the properties of matter in bulk—as in rubber or plastic materials—or to the biological specificity of the macromolecule itself in the living organisms, as is the case for proteins or nucleic acids. But it may be reasonable to ask whether it is of any interest to spend so much time and effort in order to describe more accurately the complicated wriggling of a worm-like molecule in its solution.

This question may be answered in a number of ways. First, methods which are widely used for determining molecular weights give—as is the case in the scattering of light—morphological parameters, and the very straightforward curiosity inherent in a scientist's mind would have to be arbitrarily restrained if he were not to try to understand their meaning. Secondly, and more important, the morphological results may lead to significant improvement in the knowledge of the structure itself. Since ρ , for example, depends on steric hindrances, its value depends in principle on the sequence of the atomic groups in a chain. Though it could be slightly changed when head-to-head arrangements are changed to head-to-tail, the effect is much larger when branch-

ing occurs. In fact, the determination of morphological parameters is a quite useful way of investigating branching in high polymers.

The third reason appears to me to be the most important one. I have implicitly assumed, in the foregoing discussion, that all the molecules in a solution were identical. Actually, this is not so. A sample of high polymer coming from an autoclave, as well as a sample of nucleic acid extracted from a chromosome, contains a mixture of different molecules. It is then of the utmost importance—for the improvement of our fundamental knowledge in chemistry as well as in biology—to analyse this heterogeneous or poly-disperse medium. The different species have to be characterized and, if needed, separated. This is very often done by using their difference in solubility; but it can also be achieved by using their difference in morphological parameters (after all, this is the principle of Svedberg's experiments on proteins), and this method is sometimes more direct and can lead to much clearer results. There is little doubt that it will be one of the most efficient means of resolving this problem, which is one of the most irritating in the present state of our knowledge.

As a conclusion, the morphology of large molecules, which is a new and well-defined chapter of physical chemistry, is essential for increasing our knowledge on macromolecules. Of course, this part of science has not the relish of, for example, nuclear physical chemistry. If the first half of this century be thought of as the era of the dawn of nuclear bombs and reactors, perhaps the argument could be advanced, without daring too much, that during the second half the synthesis of materials replacing the traditional natural products and our increased knowledge of fundamental biological processes may in their turn, though in a less spectacular way, weigh very heavily on our future. In this field the morphology of large molecules plays a modest but unquestionable part; it would be an error to misunderstand it.

CHEMISTRY AND CROP NUTRITION

THE problem of providing adequate food for an increasing world population, and the disastrous and far-reaching consequences of inadequate nutrition, are perhaps more widely realized now than ever before. But it is improbable that it is clearly and universally realized that the ultimate source of our food is the soil and that, were it not for the application of science to agriculture, famine would have overtaken us in Great Britain as a result of an increase in population from ten and a half to forty-nine million during the past hundred and fifty years. This was clearly brought out by Sir William Ogg, director of the Rothamsted Experimental Station, in the ninth Dalton Memorial Lecture, given in Manchester on October 28 under the auspices of the Royal Institute of Chemistry. In the Lecture, which was entitled "Chemistry and Crop Nutrition" and has since been published*, Sir William discussed the

contribution of science in general, and of chemistry in particular, to the maintenance of soil fertility.

Early manorial practice, with little or no understanding of its theory, relied in the main upon animal manures, and it was not until early in the nineteenth century that scientific ideas about manuring began to develop as the result of the work of de Saussure, Boussingault, Liebig and others on the Continent of Europe and of Lawes and Gilbert in Britain. The discovery by Lawes in 1842 that treatment of mineral phosphate with sulphuric acid resulted in the production of the phosphatic fertilizer superphosphate, and the setting up of a factory by him for its manufacture, were the beginnings of the modern fertilizer industry.

Lawes and Gilbert during fifty-seven years of active collaboration at Rothamsted carried out investigations into the principles of crop nutrition, the results of which laid the foundations of our present knowledge of manuring. They succeeded in showing the long-term effects of nitrogen, phosphate

* Royal Institute of Chemistry. No. 5: Lectures, Reports and Monographs Series of the Royal Institute of Chemistry. Pp. 13. (London: Royal Institute of Chemistry, 1955.) 3s.

and potash, both singly and in combination, and some of their field experiments, the classical plots, have been continued at Rothamsted to the present day. Their pioneer work was followed by the use of increasing quantities of nitrogenous, phosphatic and potassic fertilizers in addition to the traditional organic manures. Supplies of phosphatic fertilizers presented no problem since there were known deposits of naturally occurring rock phosphate, and in 1861 the commencement of the working of potash salt deposits ensured a supply of potassic fertilizers. Not until forty to fifty years ago, however, when fixation of atmospheric nitrogen on an industrial scale became possible, could adequate supplies of nitrogenous fertilizers be assured.

Sir William directed attention to the recent rapid rise in fertilizer consumption in Britain, the need for fertilizers being accentuated by intensification of cropping and reduction in imports of animal feeding stuffs. A wide range of fertilizers is now provided by modern chemical industry. In addition to ammonium sulphate, superphosphate and basic slag, such nitrogenous and phosphatic fertilizers as liquid ammonia, ammonium nitrate, calcium nitrate, urea, nitrophosphate, triple superphosphate and silicophosphate are available. Supplies of potassic fertilizers are still directly dependent upon deposits of potash salts in various parts of the world. Other major plant nutrients, apart from nitrogen, phosphorus and potassium, include calcium, magnesium and sulphur, and the significance of these was referred to by Sir William; there are also the trace elements (iron, manganese, copper, zinc, boron, molybdenum and chlorine) which, when deficient in the soil, and in some cases when present in excess, are responsible for reduction in crop yield or for disease in both crops and stock.

The precise determination of the manurial requirements of crops is a matter of no little difficulty. Different soils of varying fertility vary in their response to fertilizer application, and that section of the lecture which Sir William devoted to soil testing makes it quite clear that soil fertility cannot be completely explained in chemical terms, since biological, physical and climatic factors are involved also. Total chemical analysis of soil reveals only the quantities of potentially available plant nutrients.

Arbitrary chemical methods for determining the amounts of phosphorus and potassium in the soil that are available to the plant, and the amount of lime necessary to correct soil acidity (the lime requirement), have been developed, and the results, correlated with those of field experiments, can be interpreted in terms of fertilizer application to crops. Nitrogenous manuring, however, still lacks a reliable method of soil analysis upon the results of which guidance can be given, and although field experimentation has provided many useful data, more precision is desirable.

The phenomenon of base exchange in soils and the nature of the clay and humus of soils are of first importance in crop nutrition. Sir William dealt briefly with the researches which have increased our knowledge in this connexion and directed attention to the practical application of the results of these researches. Sound manurial practice involves the maintenance of a suitable balance between the amounts of the various exchangeable cations, and a further application of the principle of base exchange is the use of gypsum in the reclamation of saline and

alkali soils in various parts of the world, and of soils flooded by sea water. By the release of exchangeable sodium ions from the soil colloids and their replacement with calcium ions, the deflocculation of the soil colloids is prevented and a favourable soil structure for plant growth ensured. New techniques applied to the study of clay and humus have revealed properties intimately concerned with the physical conditions of soils and with their capacity to take up and retain plant nutrients.

Lastly, Sir William discussed the relationship between organic manures and fertilizers, pointing out that in Britain half the food for crops still comes from farmyard manure, which also improves soil texture and enhances the capacity of the soil to retain water and plant nutrients. Fertilizers, however, are essential since farmyard manure may be deficient in necessary plant nutrients, and moreover, the amounts of organic manures available are not sufficient to meet the needs of present-day intensive farming. The contentions of those who are opposed to the use of fertilizers and who condemn all chemical aids to agriculture on the grounds that there is some vital principle present in organic manures which must be transmitted to the soil if crops, livestock and the human population are to remain healthy, are without scientific foundation. The alleged harmful effects of fertilizers existed before they were discovered and are rife where they have never been used.

This Dalton Lecture was a reminder that, besides his world-famed work in chemistry and atomic theory, John Dalton made notable scientific contributions to meteorology; all agricultural scientists concerned with the water requirements of crops owe to him the first clear ideas of the nature of the evaporation processes, and Dalton may be said to have laid the foundation for modern work in this field.

J. S. WILLCOX

OBITUARIES

Prof. W. M. H. Greaves, F.R.S.

W. M. H. GREAVES, Astronomer Royal for Scotland and professor of astronomy in the University of Edinburgh, who died suddenly on Christmas Eve at the age of fifty-eight, was one of that distinguished series of Cambridge men who have held the Isaac Newton Studentship. His published papers cover a wide range of astronomical subjects, from perturbation-theory to geomagnetism; but his principal interest was the use of photography for the study of the spectra, and especially the continuous spectra, of stars. His appointment as chief assistant at Greenwich, in 1924, gave him his initial opportunity in this field, and he seized and developed it with characteristic enthusiasm. The 30-in. reflector, mounted on the same assembly as the 26-in. refractor (to the great inconvenience of both), was all that was available for such work at the Royal Observatory of that day, but Greaves took such obstacles in his stride. The rather less obvious (but much more formidable) challenge presented by the Greenwich sky was met by rigorous adherence to well-considered rules for observing, and the small probable errors of the results which were obtained testify to the judgment, as well as the courage, which lay behind the whole programme. Six years after his arrival at Greenwich,