THE ROYAL SOCIETY

ANNIVERSARY ADDRESS BY Dr. E. D. ADRIAN, O.M., P.R.S.*

AWARD OF MEDALS, 1953

Copley Medal : Prof. A. J. Kluyver, For.Mem.R.S.

PROF. A. J. KLUYVER has held the chair of microbiology at Delft since 1921 and has become a world authority on general microbiology and the biological approach to its problems.

In 1923 he made a survey of natural processes known to occur through the agency of micro-organisms, and this survey has been the cornerstone of his work for almost twenty years. Impressed by the bewildering variety of substances (both inorganic and organic) used by these organisms for their growth processes and by the equally great variety of substances formed as the end-products of metabolism, he sought some underlying uniformity in the basic types of chemical change which occurred. Devoting himself mainly to bacterial fermentations, he found this uniformity in the extension of the concepts of Wieland and Thunberg that biological oxidations occur by successive transfers of pairs of hydrogen atoms to a suitable acceptor. His views were confirmed by a series of studies covering all the principal bacterial fermentations of carbohydrate. These researches also led him to believe that, in spite of the many and varied products formed, the degradation of carbohydrate took place stepwise by a series of simple reactions leading to a limited number of common intermediates. The initial stages were alike and the variation came later through the differing enzymic constitution of the cells and the differing effects of changes in the environment on such enzyme reactions. These views have been amply confirmed and, apart from its broader implications, the work on fermentation remains a source of some of the most accurate data in the field.

Kluyver's views on the uniformity of basic cell processes in all types of cells are now widely accepted and form the basis of comparative biochemistry (a term first used by Kluyver himself). As early as 1931 he pointed out the advantages of micro-organisms for this kind of work, not only because of their biochemical versatility, but also because of the relative ease of working with them under fully controlled conditions.

Kluyver's research and thought have always been directly towards the ultimate problem of the life of the organism in its natural environment, and his broad and critical knowledge of all branches of microbiology has been an inspiration to his pupils, many of whom, in various countries, are in the front rank of microbiologists. His scientific eminence was recognized in his own country by his election a few years ago to the presidency of the Royal Netherland Academy of Sciences.

Royal Medal (A) : Prof. N. F. Mott, F.R.S.

Early in his career, Prof. N. F. Mott's work in the field of atomic collisions attracted widespread attention. He was the first to show that Rutherford's scattering law holds in quantum mechanics, and to give an accurate theory of the effect of symmetry in scattering problems. When, at the age of twenty-seven, he became professor of theoretical physics at Bristol, he abandoned this subject for that of the theory of metals and alloys, and within a few years he was recognized as one of the leading international authorities in this field. His papers on electronic bands in metals and on the electrical conductivity of alloys and its temperature coefficient have markedly influenced the lines of experimental approach in a field in which the literature was already vast. He has also contributed to the important problem of metals under strain.

Later, he turned to semi-conductors and insulators, throwing light on the physical processes involved in the formation of oxide films and in the electrical conductivity which can be induced by various means in polar crystals. His theory (with Gurney) of the formation of the latent image in a photographic emulsion has found general acceptance, and has stimulated fresh experimental work in research departments of the industry.

During the Second World War, as superintendent of theoretical research in the Armament Research Department at Fort Halstead, he made an outstanding contribution to the theory of the fragmentation of shell and bomb cases under the effect of the explosive charge, and on his return to the H. H. Wills Laboratory at Bristol he has directed work of great importance on the mechanical properties of materials. Mott's personal contributions have been mainly to the theory of plastic deformation in metals, developing the understanding of bulk behaviour in terms of microscopic derangements of the crystalline structure. His ability to establish close and effective association between theorists and experimenters is shown by the outstanding advances which have been made at Bristol under his direction, in the various branches of the physics of materials.

Royal Medal (B) : Sir Paul Fildes, O.B.E., F.R.S.

Although the outstanding contributions of Sir Paul Fildes to the science of bacteriology have come from his researches in bacterial chemistry, his earlier work on the cultural requirements of the influenza bacillus and some of its relatives added materially to our knowledge of the genus *Haemophilus*, and his brilliant studies of the behaviour of the tetanus bacillus and its spores *in vivo* and *in vitro* were a major contribution to the natural history of this micro-organism and the disease it produces.

This work brought to Fildes the conviction that full knowledge of nutritional requirements was essential for a proper understanding of the life-processes of bacteria. He gathered a small team of bacteriologists, chemists and biochemists which was formally established as a Medical Research Council Unit in 1934, and together with the late Dr. Marjory Stephenson he was largely responsible for the development of chemical microbiology in Great Britain. The period 1930–40 saw the discovery by the Unit of a number of hitherto unrecognized

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bacterial growth factors (for example, nicotinamide, uracil, glutamine) and the establishment of the detailed amino-acid requirements of several organisms. Concurrently, the specialized technique required was being worked out and has contributed largely to that in common use throughout the world to-day.

Fildes was always interested in the wider aspects of bacterial nutrition and early showed that organisms could be 'trained' to synthesize essential nutrients such as amino-acids. This field has been intensively developed, particularly since the advent of modern biochemical genetics, in other laboratories.

Fildes believed that the inhibitory action of some anti-bacterial agents might be due to interference with the metabolism of essential nutrients. The Unit's outstanding achievement in this field was the demonstration that sulphonamides act by inhibiting the utilization of *p*-aminobenzoic acid. This concept has stimulated an enormous volume of work on the possibility of designing anti-bacterial substances which might prove useful therapeutic agents or valuable tools in biochemical research, and it has also proved of great value in studying biosynthetic pathways.

Fildes's work during the War was outstanding, and since his retirement he has continued his work on chemical aspects of microbiology, and with the aid of young collaborators is adding significantly to knowledge of bacteriophages.

Davy Medal: Sir John Lennard-Jones, K.B.E., F.R.S.

Sir John Lennard-Jones's principal contributions have been to the modern theory of valency and molecular structure. In 1929 he published papers which laid down the foundations of the so-called molecular orbital method for the discussion of diatomic molecules. Among its first successes was the clarification of the triplet nature of the state of the oxygen molecule O_2. The foundation thus laid was built upon by very many authors, who applied the method to the analysis of the complex relations among the numerous group of organic compounds known as conjugated molecules. Almost an entire branch of the modern literature now consists of what are virtually applications of the original Lennard-Jones technique, and it has been shown that many subtle and surprising properties of such compounds follow from their structure in an intelligible way.

With a series of colleagues he has extended the theoretical treatment of the liquid and solid states. He has made calculations of the interatomic forces in the rare gases and other simple substances, and used the results to formulate a law of force applicable to ions in crystals. With the aid of this the lattice properties have been calculated and the results have illuminated the general picture of the solid state.

His papers on the liquid state have dealt with fundamental properties such as boiling points and critical temperatures, and further increased our understanding of the relations between molecular forces and the properties of substances.

As a complement to this abstract theoretical work, Lennard-Jones worked throughout the Second World War and after on various problems of vital practical importance connected especially with ballistics. In 1942 he was appointed chief superintendent of the Armament Research Department, where he bore extremely heavy and complex responsibilities. Later, he was chief scientific officer to the Ministry of Supply, and has now succeeded Lord Lindsay as principal of the new University College of North Staffordshire.

Hughes Medal: Sir Edward Bullard, F.R.S.

Sir Edward Bullard's earlier research work, on atomic physics, was done in the Cavendish Laboratory under Lord Rutherford, and it was Lord Rutherford who specially recommended him to Sir Gerald Lenox-Conyngham as suitable to undertake research in the Department of Geodesy and Geophysics, Cambridge. In that Department, where for some years he was Smithson Student of the Royal Society, he carried out a notable series of investigations of far-reaching importance. His clear insight and experimental skill enabled him to tackle difficult problems with a directness and freshness of approach that made them appear deceptively simple.

Bullard's determination in 1932 of the value of gravity at a number of stations in terms of the value at Cambridge was achieved by comparing the time of oscillation of a pendulum swinging at Cambridge with the time of oscillation of a similar pendulum swinging simultaneously at a field-station. These results were of considerable geophysical interest, and were followed by similar interconnexions by Bullard and others between pendulum stations in Great Britain; in 1936, the available modern gravity determinations, mainly carried out under the supervision of Sir Gerald Lenox-Conyngham, were collected and critically discussed by Bullard and Jolly, so that gravity measures in Great Britain were combined in a coherent scheme, forming a basis for later work on gravity, much of which was carried out or inspired by Bullard. The Cambridge apparatus has been lent to a number of observers in different parts of the world; the reduction and discussion of the results of some of the earlier of these expeditions (in the Sudan, Tanganyika and Cyprus) were carried out by Bullard.

In 1938 he initiated a series of expeditions in submarines for the determination of gravity at sea, using the Meinesz apparatus to investigate the continental shelf to the west of the British Isles. Meanwhile, with geophones of his own design, he delineated the palæozoic floor of East Anglia.

Many discussions had already been published of the thermal gradients in bore-holes, and it had been thought that the rate of outflow of heat differed markedly in different parts of the world; but the heat conductivity had never been measured on the actual bore-hole specimen. This unsatisfactory state of the subject was largely cleared up by Bullard, whose investigations in South Africa showed from measurements of heat conductivity of the rocks at different horizons that the rate of upward flow of heat across any section of a given bore-hole was the same. Further, a critical discussion of the data showed that the outflow is sensibly the same in all the continental regions of the globe. There remained the question of heat-flow through the ocean floor. This was first determined by Bullard in 1949; he devised a hollow steel 'spear' which could be driven vertically into the ocean sediments and left for about thirty minutes in order to reach thermal equilibrium. Experiments carried out with this apparatus in the Pacific Ocean have indicated an outflow of heat which is much the same as that through the continents, though determinations made in the Atlantic by Bullard in 1952 gave a rather lower heat-flow.

In recent years Bullard has written a number of important papers on the causes of the earth's magnetic field and, despite the heavy demands of administrative work as director of the National Physical Laboratory during the past four years, he has contrived to continue his own geophysical researches and to inspire and facilitate the researches of others.

THE GROWTH OF NATURAL KNOWLEDGE

The object of the Royal Society is the improvement of natural knowledge. It began when the search for this kind of knowledge was little more than the amusement of the curious, and we have now reached the stage when it increases so rapidly that there is not enough paper to be found for printing all that comes to light every year. It is true enough that the early virtuosi had no abundance of paper. Isaac Newton's letters, soon to be published in a collected edition by the Society, are written as closely as possible, and he and his contemporaries made their notes on every scrap of paper they could find. But what troubles us now is not the scarcity of writing material but the abundance of finished manuscript waiting to be published. We know, too, how little of it we are likely to read ; although we are bound to regret the slowing down of productive work in academic science during the war years, I think those years will be recalled by many of us as the time when we had no piles of unread journals and reprints to be ashamed of. Nowadays the piles would be even larger if publication were easier, for scientific research has become one of the major interests of mankind and we cannot escape the consequences.

One consequence, which weighs heavily on me at the moment, is that it has become increasingly difficult to pick out some special discovery or specially active line of work to bring before the annual meeting of the Royal Society. There has been great activity in many lines ; but for the time being we seem to have passed the stage of really startling discoveries. In the most promising fields there are already so many scientists at work that the general line of advance can be foreseen for a few years at least. We cannot, of course, foresee the sudden illumination which comes from time to time to put some branch of science on a new footing ; but it would be safe to foretell that very soon the chemists will have synthesized more natural products, that we shall know much more about the structure of the proteins, about the nature of viruses and the action of enzymes, about the products of atomic disintegration and the physical properties of matter at very high and very low temperatures. Valuable discoveries will certainly come in all these fields ; but we are well prepared for them : they will not startle us unless they show some fault in the accepted theories, and most of them are already based on a wide range of evidence.

The rapid expansion of scientific research has another consequence which must be of some concern to a Society which deals as we do with the whole domain of natural knowledge. In the past it was a domain with isolated fields, each yielding a different crop and mostly separated by tracts of unexplored country. It was easy to classify scientists as chemists, physicists, zoologists and botanists, and so on. They had different data to bring together and a different way of dealing with them, with a different vocabulary and different apparatus ; as soon as we were through the door we knew whether we had come to the right laboratory. But it is becoming far more difficult nowadays to decide where the boundaries should be drawn ; the major fields are experimenting with new crops, and the barren areas which used to separate them have begun to yield fruit and to attract workers from distant regions. Mathematics and physics and chemistry lead without a break into the biological fields, and it needs more than a casual glance to tell whether we are in a laboratory which studies the atom or the human brain.

We should all rejoice that the old barriers are yielding, for we aim at a single inclusive system of the world, one that will cover all the immense variety of natural events. Yet they have an immense variety and it is still necessary to classify them. For a society like ours the classification ought not to go into much detail. There must be committees with suitable labels ; but if we are to judge the importance of different lines of inquiry there must be as much overlapping as possible, so that a new line of work can be considered by experts who are not all biased in the same direction. But in their own laboratories the different branches of science must be free to take their own course and, though the major groups are content with their traditional labels, the pioneers who work in new territories need new ones. We are all too familiar with the passions aroused at the thought of independence from 'overlords' who were once powerful, and so we cannot be surprised when a group of workers in a new field demand a label which does not saddle them with wider scientific loyalties. No one ought to, or can, stop them from having their own journals and meetings, and if they want it they must be allowed the satisfaction of using a sign language that no one else understands. The chief difficulty arises in connexion with the international organizations which maintain contact between the scientists of different countries. They perform a valuable, in fact an essential, service, and this is recognized by the financial support which they receive from national governments by way of direct subscription or indirectly by way of such bodies as Unesco. But the available funds are limited, and every year new international unions arise to claim acceptance by the International Council of Scientific Unions and of the countries which support it. Advisory bodies faced by this multiplication of clients are already finding it hard to weigh the claims of new and old, of the small bands of enthusiasts eager to meet colleagues scattered over remote countries, and of the powerful established societies with congresses attended by thousands and an elaborate organization to keep in being.

The problems of the borderline subjects and of the specialist groups are bound to grow as the content of natural science increases ; but they are signs of progress and will no doubt be settled as they arise, by reasonable compromise. I have mentioned them chiefly to emphasize the more general difficulty of keeping our enormous territory in focus. It has long ago passed the competence of one mind, and it will need a more and more highly organized co-operative effort if we are to make the best use of our time.

The ability to make such an effort is, of course, our birthright. The human brain surpasses that of other animals in its capacity for what Henry Head called 'symbolic thinking and expression' ; it is because we can communicate our thoughts that two heads are better than one, and because we can express the results in permanent form by pictures or writing that each generation has a greater store of knowledge than its predecessors. Individually we can be specialists, because, in Isaac Newton's phrase, we stand on the shoulders of giants.

We are rapidly improving the mechanical devices which ought to help this upward progress. We can pay a week-end visit to a colleague in California if our ideas are still too vague to be reduced to writing; and besides the microfilms and new printing and copying devices there are the electrical recorders which are now so often used for ensuring that no single word spoken at a scientific congress shall be lost to posterity. These potential benefits are not at the service of scientists alone, but we must assume responsibility for their introduction. Aeroplanes and tape recorders can certainly assist scientific research, but only if we keep them as servants and not as masters.

It would be easier to keep our instruments and records in their proper place if we knew more about our own capacities, about our ability to profit by discussion or to extract what we need from a store of information. We have no scale for measuring such abilities, but we have a new line of approach which will certainly help their investigation. When the British Government in 1823 gave Charles Babbage a substantial grant for his calculating machine the technical difficulties proved insuperable; but Babbage could construct a machine on paper which should have been able to solve most of the problems which are dealt with by the new electronic instruments. It could even work miracles, for Babbage pointed out that his machine could be arranged to produce at intervals of a thousand years or more a single abnormal event which might well appear to be an interference with the course of Nature. With our modern instruments, miracles of calculation are possible because the operations can be carried out at an unimaginable speed; a vast number of figures must be dealt with and some of them must be stored for a limited time, but if the machine is to be of reasonable size they must be stored no longer than they are needed and in a space which can be constantly used for new sets of figures as the calculation proceeds. Thus the record must be of a kind which will vanish instantaneously and completely when the need for it is over.

One way of achieving this is to arrange for each item to set up a cycle of operations, electrical or mechanical, which will repeat itself indefinitely at a high rate but will cease immediately when fresh items appear. In the system due to Prof. F. C. Williams, 1,000 digits can be kept alive as long as they are wanted on the screen of a cathode ray tube, and the value of each can be read with a delay of not more than a few microseconds. There would be no great difficulty in arranging so that a repetition of the cycle for an hour or more should induce some structural change in the machine, a storage which would not need a constant supply of energy to maintain it; but there would be little to be gained, for it is better that the machine should start each morning as a clean slate. Its code of instructions can be given a permanent form, but the cycles of activity which keep each digit alive are ended abruptly when the current is turned off.

The human brain can neither remember nor forget with such precision—if it could we should be in a far better position to assess its powers. There are too many variables to be considered. The items of information coming from the sense organs are not all treated in the same way: a few are given priority for the storage process and many are unnoticed; and signals which reach the brain may be stored for a time as self-perpetuating cycles of activity, but before long the traces leave some more enduring change which does not need constant renewal. Thus the telephone number we have to dial can be kept alive in our mind by constant repetition like the numbers in a calculating machine; but we cannot be sure of forgetting the number completely when we have made the call.

The formation of some kind of stable trace can be inferred from the fact that memories survive periods when the brain is almost completely at rest. We must start each morning with our brain structure modified by what happened to it the day before: the deepest sleep or anæsthesia or coma, in fact the most complete cessation of activity short of death, will not make the brain a clean slate with no traces of our mother tongue or of the manual skills we learnt in infancy. Thus we may be able to say precisely how many items of information can be carried in an electronic machine for how long, but we cannot hope to answer the same questions for the human brain until we know far more about the nature of its storage processes. What we can learn from the machines is how our brains must differ from them.

There are already some indications of the kind of alteration which may be produced in a nerve cell by repeated activity. It is well known that repeated stimulation of the nerve cells of the brain produces an increased responsiveness which can last a minute or more; and Eccles and his colleagues have recently shown that even in the spinal cord, the function of which is purely executive, a long period of inactivity leads to a loss of responsiveness which is restored by a short period of enforced activity, and when restored tends to persist for a matter of hours. What physical or chemical changes are responsible for these alterations is still unknown, but we have a new method, introduced by Eccles, for studying the biophysics of the nerve cell by the use of a microelectrode thrust into its interior. The method was first used in the study of muscle fibres: its extension to the nerve cell has already given important results and cannot fail to give more.

It is naturally more difficult to study the biochemistry of the individual nerve cell than to study its electrical properties, but the storage process may well involve a chemical as well as a physical reorganization. If the cell chemistry of a grown man can bear the mark of an infection with measles in childhood, it is not unreasonable to suppose that the nerve cell constituents are plastic enough to be modified by past activity. Evidence accumulates in favour of the view that the transmission of signals from one cell to another depends on the release from the cell terminals of stimulating molecules, and their rapid destruction by enzymes. The stimulating molecules so far discovered, acetyl choline and perhaps *nor*-adrenalin, are of relatively simple structure; but we know too little about the enzymes to be sure that the destruction of the stimulus will always proceed at a uniform rate uninfluenced by the past history of the cells.

I have reason to be impressed by the versatility of the nerve cell in relation to chemical stimuli, for I have been trying for some years to find out how the olfactory organ enables us to distinguish an immense variety of molecules brought to it in the air. The receptor cells number several millions but they differ very little in external appearance; and for a time I thought that the discrimination of one smell from another depended more on the particular regions stimulated than on the particular receptor cells. But it is becoming more and more certain that there are marked differences in the specific sensitivity of the receptors. One group will react most readily to aromatic molecules, another to particular terpenes and so on. These differences are no doubt permanent, but they show that cells which look alike may have some physico-chemical organization which makes them react quite differently to a particular stimulus. It is perhaps to be hoped that the cells of our brain have a more uniform constitution, and that memory traces depend on biophysical rather than biochemical alterations. It will certainly be easier to detect the former; yet until we know more about the nature of these traces, we cannot begin to understand what is by far the most important property of the brain.

OIL POLLUTION OF THE SEA

AT the International Conference on Oil Pollution of the Sea, which was held in the Lecture Hall of the Institution of Electrical Engineers, Savoy Place, London, on October 27, representative private citizens of many nations met together for the first time in a concerted effort to press for action on the evils caused by oil pollution of the sea. The Conference was organized by the Co-ordinating Advisory Committee on Oil Pollution of the Sea, of which Mr. James Callaghan is chairman. This is an independent Committee composed of representatives of the interests in Great Britain which are most affected by oil pollution, namely: Association of Municipal Corporations, Association of Sea Fisheries Committees of England and Wales, Council for the Preservation of Rural England, Council for the Preservation of Rural Wales, County Councils Association, General Council of British Shipping, International Committee for Bird Preservation (British Section), River Boards Association, Royal Society for the Prevention of Cruelty to Animals, Royal Society for the Protection of Birds, Rural District Councils Association, Universities Federation for Animal Welfare and the Urban District Councils Association, with individual members who are experts on different aspects of the question.

In the formation of the Committee in March 1952, the efforts of many organizations which had for years been working individually to secure a solution of the problem of oil pollution were co-ordinated and canalized. On July 21, 1952, the Minister of Transport announced in the House of Commons that he had decided to appoint a committee to consider what measures could be taken to prevent oil pollution of the sea, and on October 2 the constitution of this committee, which was entitled the Committee on the Prevention of Pollution of the Sea by Oil, under the chairmanship of Mr. P. Faulkner, was announced. The report of this Committee was published in July this year, and the purpose of the Conference just organized by the independent Co-ordinating Advisory Committee on Oil Pollution of the Sea, and presided over by Mr. J. Callaghan, was to bring the findings of this report before public opinion in all countries.

In opening the Conference, the Minister of Transport, Mr. Alan Lennox-Boyd, stated that it is realized in the United Kingdom that legislation is required to implement the recommendations of the Faulkner Report; but it is also recognized that action by one country alone, though important, is not enough. He then announced that the Government is taking steps to call a conference of maritime governments to consider how the trouble could be ended. He had in mind that it might be similarly organized to the Conference on Safety at Sea, held in 1948, which was followed by swift action, and concluded by stating that he hoped its recommendations would be as speedily adopted.

Lord Hurcomb, president of the Society for the Promotion of Nature Reserves and, until recently, chairman of the British Transport Commission, in introducing the report of the Minister of Transport's committee on oil pollution, stated that there is no dispute as to the gravity and extent of the mischief, nor is there any room for dispute as to the cause of the trouble or the remedies for it. The remedies are clear, and all that is needed is the will to apply them. He pointed out that the Minister's committee, which included two shipowners and two representatives of the oil companies, has stated in its report that "in recent years the nuisance has become intolerable". He expressed appreciation for the speed and admirable precision with which the committee has reported, and said that its inquiries have been thorough and it has pointed firmly and fearlessly to the remedies, after satisfying itself that those remedies are entirely practicable. Lord Hurcomb continued that the problem reduces to the fact that the only way to avoid polluting the sea, fouling the beaches and destroying birds, is not to put persistent oil sludges and waste into the ocean, but to separate them and to discharge them ashore. To prohibit discharge within a prescribed distance of particular coasts is a mere palliative, though necessary as an interim measure. It has been shown that even a limit of 150 miles would not give the United Kingdom a remedy, and the only long-term policy is to prevent the discharge of persistent oils into the sea altogether. For this to be practicable, suitable and adequate facilities for the reception of oily waste should be provided at all loading terminals and repair ports throughout the world. Lord Hurcomb concluded by stating that weary years of international argument in the hope of securing complete agreement should not be contemplated, and asked that a date for achieving the ultimate policy should not be timidly fixed too far ahead.

Mr. Donald F. Anderson, chairman of the General Council of British Shipping, spoke on the problem as the British shipowner sees it and stated that their general attitude is already known by the solid fact that British shipowners have accepted the report and recommendations of the Faulkner Committee, and that they decided as soon as it came out to put into practice some of the measures. He stressed that, though they are doing all they can to help in solving the problem, it would take more than action by British shipowners before there could be any material improvement, and he alluded to the vast amount of shipping under other flags which goes up and down the English Channel without touching the United Kingdom. He concluded by saying that goodwill among shipowners of the leading maritime countries is not enough. If the aim of preventing oil getting into the sea anywhere is to be reached, this can only be achieved if vessels of all flags are bound by a convention among all the nations with ships that sail the seas.