THE ROYAL SOCIETY

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

AWARD OF MEDALS, 1954

Copley Medal : Sir Edmund Whittaker, F.R.S.

WHITTAKER is probably the best-known British mathematician by reason of the numerous, varied and important contributions which he has made and the high offices which he has held. For many years he was the head of the flourishing mathematical school at Edinburgh which owes its whole being to his activity.

His work shows extraordinary versatility. He has written five outstanding books, on entirely different subjects, and some fifty to sixty papers which touch on almost every branch of pure and applied mathematics. Of his books, perhaps the most important is "A History of the Theories of Aether and Electricity", which he has just completely rewritten in a second edition of two volumes. This great work gives a critical appreciation of the development of physical theory up to the year 1925. All his writings show, besides their more technical qualities, powers of arrangement and exposition of a most unusual order ; and his treatises of dynamics and analysis have had a considerable influence on mathematical thought both in Great Britain and abroad.

It is only possible to mention a few of Whittaker's original contributions to knowledge (beyond the considerable number absorbed in his books). He has made important additions to the theory of the solution of differential equations, ordinary and partial, by definite integrals ; to the theory of Lamé and Mathieu functions, the functions of the elliptic and parabolic cylinders, and the integral equations associated with them ; to the theory of interpolation ; and to the theory of the solution of dynamical problems by trigonometrical series. He has also, in recent years, made a number of interesting contributions to the pure mathematics of relativity, electromagnetism and quantum theory. The astonishing quantity and quality of his work are probably unparalleled in modern mathematics, and it is most appropriate that the Royal Society should confer on Whittaker its most distinguished award.

Rumford Medal : Dr. C. R. Burch, F.R.S.

Dr. Burch has made outstanding contributions in the development of new techniques for the production of high vacua. Using a molecular still of his own design, he produced a range of oils, greases and waxes having very low vapour pressures. He developed modified diffusion pumps suited to these low vapour-pressure oils which in very many cases have made the use of refrigerants unnecessary and have superseded the mercury diffusion pump. With these pumps and various other devices he pioneered high-vacuum engineering as we know it to-day. Some of its products—continuously evacuated valves, high-voltage tubes, X-ray crystallographic tubes, aluminizing tanks, etc.—he also designed in the early period. These developments have formed an essential part of the design of the high-vacuum devices used in the production of high-speed particles.

Many of the joints in Burch's original pieces of apparatus involved the use of flat surfaces, and he became interested in the science of optics necessary for the study of the production of surfaces to very accurate shapes, and devised a technique for making microscopic phase-retarding disks needed for testing them by phase contrast.

This was one of the techniques used in his next achievement—the perfection of the reflecting microscope. Although the principle of the instrument has long been known, Burch has been responsible for making it practically useful. His theoretical consideration of the problem showed for the first time the conditions under which good results can be expected and the limitations which must be faced.

The introduction of reflecting microscopes may well produce revolutionary changes in many aspects of microscopy, including microbiology. Since the system is wholly achromatic, it remains at the same focus for all wave-lengths. Identification of substances by plotting the absorption curve in the ultra-violet can now be made by the use of a reflecting microscope and a continuous spectrum, and the possibilities of microscopy in the infra-red are greatly extended.

Royal Medal (A) : Sir John Cockcroft, K.C.B., C.B.E., F.R.S.

Sir John Cockcroft turned to physics after an early training as an engineer. In conjunction with Dr. E. T. S. Walton he was the first to transmute elements by purely artificial means, setting the crown on Rutherford's work which had proved that bombardment by α-particles from radioactive substances could transmute many of the lighter elements. Cockcroft's work in this field is outstanding both for its scientific consequences and as a discovery in technique. The original experiments of Cockcroft and Walton are the seed from which has grown the whole new science of nuclear chemistry, in which artificially accelerated particles are the reagents which produce varied changes in the nuclei of elements which they bombard. Indeed, a large fraction of the researches now being carried out in the physics laboratories in Great Britain and in the United States arise directly from his work.

Shortly before the Second World War began, Cockcroft had realized the great importance of radar methods of aircraft detection for the defence of Britain, and his influence at the Cavendish Laboratory and later at Malvern was of decisive importance in the development of radar.

In 1944 Cockcroft returned to nuclear physics and was in charge of a large group of British, French and Canadian scientists working on plutonium production, first in Montreal and then at the newly developed

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* Delivered at the Royal Society on November 30.

Canadian research establishment at Chalk River. When, after the War, the Atomic Energy Research Establishment was set up at Harwell, Cockcroft became its director. Under his guidance it expanded rapidly, and at the same time provided much of the basic information needed for the large-scale production of plutonium in Britain. He has maintained a balance between pure and applied research which has built up in the Establishment a fruitful research atmosphere and has led to important new developments in the use of atomic energy.

Royal Medal (B): Prof. H. A. Krebs, F.R.S.

Prof. H. A. Krebs has made unique contributions to our understanding of the intermediary metabolism of nitrogenous substances and of carbohydrates in living cells, and in his recent work he has helped to bridge the gap which exists between our understanding of the chemical activities of cells and of the way in which these activities help to maintain ionic gradients within the living organism. In the course of these researches he has devised many valuable new methods for the study of cell metabolism.

The main advances for which he has been responsible are numerous and varied. In the realm of nitrogenous metabolism he was able to demonstrate the catalytic function of ornithine in the conversion of ammonia and carbon dioxide to urea by liver tissue. In his work on amino-acid metabolism he showed that kidney and liver tissues contain the system which oxidizes L-amino-acids, while kidney extracts have an active D-amino-acid oxidase; these important enzyme systems attack amino-acids to form ammonia and the corresponding keto-acids.

He discovered the metabolic reaction by which proline can be converted into glutamine, and he has shown the basic significance of glutamine in the inter-related metabolism of amino-acids and carbohydrates, and also in the transport of ions across cell membranes.

His greatest discovery is the tricarboxylic acid cycle, commonly referred to as the Krebs citric acid cycle. This is now accepted as one of the principal means of biological oxidation. Its basic significance in cellular metabolism scarcely needs emphasizing, for it accounts for the complete oxidation to carbon dioxide and water of the two-carbon fragments which arise in the intermediate metabolism of most kinds of foodstuffs.

In his recent work he has helped to clarify the means by which ions and small molecules are transported within the cell.

In 1953 Krebs was awarded the Nobel Prize for Medicine, jointly with Fritz Lipmann, and the award is an indication of the great value of his discoveries to the advance of biochemistry.

Davy Medal: Dr. J. W. Cook, F.R.S.

Cook is distinguished mainly for his contributions to our knowledge of the polycyclic aromatic compounds, the carcinogenic hydrocarbons and the tropolones, including the alkaloid colchicine.

During the period 1920–28 he carried out an extensive series of investigations on derivatives of anthracenes and related complex hydrocarbons, in the course of which a new type of molecular rearrangement was discovered. He then turned to the chemistry of carcinogenic hydrocarbons and synthesized many homologues and derivatives of 1 : 2-benzanthracene which were found to be carcinogenic; from these and other studies, indications of the nature of the chief carcinogenic agent in coal tar pitch were deduced. Further, Cook was able to enunciate certain broad generalizations regarding the structural conditions necessary for carcinogenic action within this group of compounds. By fractionating 2 tons of coal tar pitch he isolated the pure potent crystalline carcinogen, and with the aid of fluorescent spectroscopy this agent was shown to be 3 : 4-benzopyrene, identical with a synthetical specimen. Thus Cook was able to demonstrate for the first time the nature of tar and certain mineral oil carcinogenic agents, results which have proved invaluable in studies of certain aspects of the cancer problem.

During the period 1939–54 Cook made outstanding contributions to our knowledge of the alkaloid colchicine and to the chemistry and synthesis of the tropolones. The novel and now accepted structure for colchicine is based almost entirely on Cook's early studies, which stimulated activity in a number of other laboratories.

More recently Cook has extended his studies to the examination of the structure of metabolic products of the carcinogen, 3 : 4-benzopyrene, and to the oxidation of benzenoid hydrocarbons by novel methods.

In these original studies Cook has tackled a series of extremely difficult and complicated problems with an exceptional knowledge of general organic chemistry coupled with great experimental ability. In the course of his purely chemical studies, Cook has been quick to detect the biological significance of his results, and his findings have provided weapons of attack, if not the keys, to a number of problems in the biological field. Of the results which Cook has achieved, it can be said that they have fundamental importance either to general organic chemistry or to biology or to both.

Darwin Medal: Dr. E. B. Ford, F.R.S.

Dr. E. B. Ford, reader in genetics in the University of Oxford, has made important contributions to all departments of genetics; and, in particular, he has extended and enriched Darwinian thought in two crucial ways: first, the reformulation of Darwinism in terms of the Mendelian theory of inheritance, and second, the extension of Darwinian theory to natural populations.

Ford is the foremost authority on the genetics of Lepidoptera. In studies of a single natural population of moths continued over many years, he was able to show that the genetic diversity of the population varied with its size. Rapid increase of numbers was accompanied by an outburst of variation; in leaner years the individual members of the population were highly uniform. Ford used wing coloration in moths of the genus *Abraxas* to demonstrate the fundamental truth that the 'dominance' of a gene is profoundly influenced by the action of other genes, and therefore by natural selection; with the effect that a factor intermediate in its expression in the heterozygous state could be caused to become dominant or recessive at will. More recent work on Lepidoptera has shown up with particular clarity the sensitivity of the response of even small natural populations to the influence of selection: in altering the genetical structure of such a population, natural selection has proved to be a more potent influence than the vagaries of random mating and random survival. As a corollary, Ford has shown that genetical variants which a superficial and subjective judgment have dismissed as being 'trivial' or of no adaptive significance cannot in reality be so regarded. This work, much of it carried out in collaboration with Sir Ronald Fisher, has clarified and strengthened Darwinian theory in a most important degree.

A complete understanding of Darwinian theory must in the long run turn upon a knowledge of how genetical factors exercise their effects in development. In this field, too, Ford has made important contributions. In collaboration with Dr. J. S. Huxley he showed that one important means by which different genes produce their several effects is by influencing the rate rather than the nature of chemical reactions. More recent work on the genetical basis of wing-coloration in Lepidoptera has been distinguished by the way in which Ford has bent chemical methods to the solution of biological problems.

A single example may be given of Ford's wider influence on genetical thought. At a time when many geneticists were still preoccupied with the analysis of single-character differences and their rules of segregation, Ford was particularly insistent on the need for appreciating the concerted and harmonious action of the assembly of genes considered as a whole, and his concept of the 'gene complex' has had an important effect on the general background of genetical thought.

Dr. Ford's work thus very evidently merits the Society's award for work "of acknowledged distinction in the field in which Charles Darwin laboured".

Hughes Medal: M. Ryle, F.R.S.

Martin Ryle is the leader in the recent developments in radio-astronomy in England. By adapting war-time techniques, he developed a radio analogue of the Michelson stellar interferometer, and he showed how it could be used to detect localized sources of radiation against a continuous background.

With these new and powerful methods he has been able to demonstrate that the solar radiation comes roughly from the area of the visible disk, and that sunspot radiation comes roughly from an area the size of the spot and is often circularly polarized. He showed that there are a large number of radio-stars, and he has detected and roughly located about a thousand of these. He measured the position of a few of them with such accuracy that the optical astronomers have been able to identify them with visible objects. He developed a Fourier analysis method for measuring the distribution of emission across the solar disk and has used it to show that this distribution is unsymmetrical and varies with time. He has used the occultation of a radio-star by the solar corona to investigate the scattering of waves by the corona. He showed that the scintillations of radio-stars were produced by scattering in the ionosphere, and he has used the observations to investigate ionospheric irregularities and their movements.

Ryle has always been very productive of theoretical ideas to account for his observations, and he has pointed out their interesting consequences for cosmological theory.

He has shown that he can pass on his ideas and his enthusiasm to others, and he is the leader of a small and able team which is making major advances in this new field.

THE DIVERSITY OF SCIENTIFIC ADVANCES

When he admits new Fellows to the Royal Society and when he presents the medals at the annual meeting, the President performs his two most pleasant and most important duties. And the range of natural science is now so vast that he need not feel embarrassed by his lack of understanding of the work which he rewards. One hundred, or even fifty, years ago there was far less to understand: we can well believe that there were many Fellows of the Society who knew at least the vocabulary and the general content of every branch of natural science. We still have a few who can survey the whole field—and perhaps we never had more than a few—but certainly it becomes every day more difficult to find scientists whose interests are wide enough to assist the advance by helping the specialists to understand one another.

There is in the Library of Trinity College, Cambridge, a collection of letters illustrating the value of such help. They were written between the years 1830 and 1860 by two Fellows of the Royal Society, Michael Faraday and William Whewell, the great discoverer seeking advice from the most learned scholar of his day. The correspondence reminds us how far we have gone in these hundred years, though it is not surprising that Whewell could assist Faraday, for both of them were exceptional people. Whewell was the Master of Trinity of whom it was said that there was no subject on which he did not speak with authority. His two books on the inductive sciences can still be read with admiration and he had made important contributions to the study of architecture, law and theology. Faraday was in difficulties with his experiments on electrolysis. He needed new terms to describe what he was doing and, having called the two poles 'electrodes', he was uncertain how to differentiate them and how to name the products of current flow. As he was anxious to avoid theoretical implications, he thought of calling the electrodes 'Voltode' and 'Galvanode' or even 'Alphode' and 'Betode'. Whewell makes no reference to this suggestion but, in a letter dated May 5, 1834, he strongly advises the terms 'Anode' and 'Cathode'. The letter continues:

> "If you take *Anode* and *Cathode* I would prefer for the two elements resulting from electrolysis the terms *Anion* and *Cation*, which are neuter participles signifying *that which goes up* and *that which goes down*; and for the two together you might use the term *ions* instead of *Zetodes* or *Stechions*."

And Faraday replies ten days later to say that he has taken Whewell's advice and ends his letter:

> "I am quite delighted with the facility of expression which the new terms give me and I shall ever be your debtor for the kind assistance you have given me."

Whewell's assistance did not end there. In 1836 he suggested the term 'dielectric', and there is a letter written about 1850 which begins:

> "My dear Sir,
> I am always glad to hear of your wanting new words, because the want shows that you are pursuing new thoughts and your new thoughts are worth something."

This time the new word he has to suggest is 'paramagnetic'.

In these days when Faraday was still pursuing new thoughts and Clerk Maxwell was still an undergraduate, it would not have been so difficult to select the most important scientific advance of the year and to point out its significance in the general store of knowledge. But now the store expands so rapidly that it is much more difficult to see where the advance has been greatest. We are farther into the mighty maze and have split up into groups, all of them too deeply engaged to consider the plan. Many of these groups, indeed, are now in territory so far from the entrance that only the grey beards can tell you how they came there—the young pioneers have learnt the dialect of the district and all their interest lies ahead.

We must face the fact that scientists to-day are hard put to it to keep in touch with one another, and that they seldom trouble to signal their position to headquarters. We need not take this too seriously. Parts of the maze may be left unexplored or may be explored twice over, but no permanent harm will come of it. Yet the different groups ought not to be left entirely alone. Though they would resent advice or patronage from those who cannot appreciate their problems, they will go more cheerfully if they are encouraged from time to time by the approval of the scientific world.

It is part of the function of the Royal Society to show this approval. We can still hope to do it effectively by the award of medals, for the achievements which they crown are of a kind which we can all appreciate, though as individuals we may not understand their full content. But the approval of the Royal Society would soon become valueless if we lost either our corporate view of the general enterprise or the close contact of our Fellows with its many special divisions. If we are to retain both, it is more than ever necessary for us to keep our programme and our whole organization under constant review. The position changes rapidly and already great care is needed to see that we are not guided too much by memories of what it was twenty, or even ten, years ago. There are fresh growing-points to demand attention, and we must be ready to accept their claims and if necessary to revise our estimates of the relative importance of established branches. No one likes to think that the special branch which he cultivates is now less fruitful than it was; but we must be careful that our approval is not spread too thin to give much encouragement to the new growths.

An Experiment in Lamarckianism

Having emphasized the need for looking forward rather than backward, I can turn with a clearer conscience to an experiment which has just been concluded and is none the less interesting for having started twenty-two years ago. It is an investigation of the late Prof. W. McDougall's claim to have demonstrated the inheritance of a reaction produced by training, an inheritance which could only be explained on the lines of Lamarck's theory. The report which has just been published is the fourth of a series by a team headed by the late W. E. Agar and more recently by Prof. O. W. Tiegs. I have a special reason for mentioning it, for to physiologists of my generation it will bring back a vivid picture of a meeting in Edinburgh thirty-one years ago. It was at the Eleventh International Congress of Physiology, and we had come to hear a lecture prepared by Pavlov and delivered in English by his son, dealing with recent developments in his work on conditioned reflexes. No one who knew Pavlov will be surprised that our attention was sometimes diverted from the substance of the lecture to the spectacle of its author listening intently to the English version, for Pavlov, like Rutherford, had a vigour of mind and body which could not escape notice. But the lecture ended with an account of some preliminary results on a new problem, that of the inheritance of conditioned reflexes, and these compelled attention because, although they were not yet conclusive, they seemed to show a positive effect. Rats which had formed a conditioned reflex to the sound of a bell bore litters which needed less training to establish the same reflex in them. It looked as though Lamarck might be right after all, that a modification acquired by the individual in consequence of its efforts to adapt itself to its environment might be transmitted in some degree to its descendants.

Pavlov returned to Leningrad, and not long after we learnt that further work had revealed a source of error and that, in fact, he could find no good evidence of the inheritance of reactions set up by training. But William McDougall, a Fellow of our Society and a distinguished psychologist, had been working on similar lines, and his experiments showed a positive effect small enough to need careful assessment but too large to set aside. McDougall gave his rats the choice of escaping from a water tank by swimming towards a light or a dark exit. They could escape in comfort by the dark exit but received a mild electric shock if they chose the light, and before long they never made the mistake of doing so. The amount of training needed to establish the habit was averaged from the performance of large numbers of rats bred from a standard stock, and it was found that with successive generations the training needed became progressively less; and that after the thirty-fifth generation the rats showed a distinct preference for the dark exit from the first time that they were placed in the tank.

McDougall continued his experiments until 1937 (he died in 1938) and replied vigorously to his critics. The most important criticism was that of F. A. E. Crew, who conducted a similar training experiment lasting over eighteen generations and found no evidence of improvement. Agar and Tiegs began their work in 1932. It has been extended over fifty generations and has involved the training of 4,654 rats; its results agree with Crew's in showing no evidence that the training of one generation makes the next need less training to acquire the same certainty of response. Their experiments confirmed McDougall's to the extent that they too obtained long-duration trends of improvement in learning-rate, but they found that they were shown equally by a control series of rats of untrained ancestry and that the effect was not sustained. It seemed to be correlated with general changes in the health and vigour of the laboratory colony, changes which had nothing to do with the training process.

The problems of inheritance cannot be studied without experiments running on from one generation to another, and the results are bound to come slowly if the organism is not one which reproduces itself in a very short time. Certainly an experiment which may last twenty years is not to be undertaken lightly, for in that time so much may happen to threaten its survival. But this one has survived all the hazards of our time, and its authors will not need to be congratulated on having achieved their purpose.

Their purpose was to examine McDougall's case for a Lamarckian type of inheritance, and they have found that the evidence is against it. Most of us would have been rudely surprised if the result had been positive instead of negative; but if their experiment had not been made, we should have had an uneasy feeling that McDougall's conclusion might after all be justified, although Crew's experiments gave it no support.

The same cause for uneasiness may arise whenever a laborious and difficult investigation has given results which seem to contradict prevailing theories but are not decisive enough to be taken without confirmation. We realize that the experiments must be repeated and that it may be a wearisome business demanding great dexterity, constant attention and the building up of elaborate apparatus. There will be little scope for originality except in the devising of further controls, for the new experiments must not differ appreciably from those they are intended to check. Most of us start with a bias in favour of the orthodox view, and as we know that the pitfalls increase with the length and complexity of the experiment, we shall be surprised if the outcome is not the expected negative. When it turns out that way, we shall be grateful to those who have cleared up our uneasiness, but glad that we could think of adequate reasons for spending our time on something else.

No doubt we shall not have spent our time more profitably. The new experiments usually reveal some unsuspected factor which made the original result misleading, and this factor may be an important clue in different problems. But work of this sort rarely meets with the recognition it deserves, and this is a good opportunity for pointing out that our general advance could not go on without it.

The advance of science must depend on the initiative of those in the front line of research. It must be the aim of each special branch to explore the alleys it has opened up, including those which are most probably blind; but as long as the branches are not controlled from headquarters, their members will decide how this is to be done. Control by headquarters is sometimes necessary: we cannot demand that we should always be left to choose our own problems, for there are periods when we must all do as we are told, periods of emergency when we are threatened by war or famine or disease and must all join in a concerted attack. In fact, as scientists we have a double responsibility, for our general aim is to advance our understanding of Nature, but we are now the members of a profession which has special responsibilities because of the way in which it can affect the whole structure of civilized life. The immediate claims of society have to be met, and for this we must be willing to do more or less as we are told. For the long-term objectives we can still do better when we are allowed our independence, but only because there are some of us who will face the laborious work when there is no other way of resolving a doubt.

THE COPLEY MEDAL AND ITS FOUNDER

By Engineer-Captain EDGAR C. SMITH, O.B.E., R.N.(Retd.)

WHEN in 1773 Sir John Pringle, president of the Royal Society, presented the Copley Medal to Priestley for his "Many Curious and Useful Experiments on Different Kinds of Air", he referred to it as "the palm and laurel of this community". An earlier president, Martin Folkes, when handing the Medal to John Harrison, of chronometer fame, had spoken of it as "this small but faithful token of their regard and esteem". Later, Davy called it "the ancient olive crown of the Royal Society", while Cuvier in his *éloge* of Priestley wrote: "La Société Royale lui décerna la médaille de Copley, que l'Angleterre considère comme le prix le plus noble auquel on puisse arriver dans les sciences. L'Académie de Paris lui accorda un prix non moins noble, l'une de ces huits places d'associés étrangers". In the eighteenth century there were few scientific societies and still fewer prizes, but to-day, in spite of the great increase in the number of scientific institutions and awards, some of the latter of which are accompanied by large sums of money, the Copley Medal with its honorarium remains what it was to Pringle, Folkes, Davy and Cuvier, although in the press of public affairs its significance is to-day often overlooked.

While this is true, it is fairly certain that few readers know much of its history or of its founder. Ever since 1736 when the first Copley Medal was struck, it has, with some exceptions, been awarded annually, and the long lists of recipients, especially those of the past and present centuries, include the names of many of the greatest men of science who ever lived, no matter what their nationality. A brief account of the founding of the Medal is given in Weld's work, "A History of the Royal Society with Memoirs of the Presidents compiled from Authentic Documents", published in 1848; but Weld knew little of Copley, and neither did the writer of the notice of him in the "Dictionary of National Biography". Thanks, however, to the researches of Prof. W. H. G. Armytage, of the University of Sheffield, much relating to Copley and his activities has been brought to light, and some of the results are to be found in Prof. Armytage's article entitled "Sir Godfrey Copley, F.R.S., 1653–1709. Some Tercentenary Glimpses through Letters to his Friends", published in *Notes and Records of the Royal Society of London* (11, No. 1; January 1954). From this it is seen that Copley was a public-spirited man of varied interests and a faithful friend and correspondent.

The exact date of Copley's birth is not known, though evidence points to the year 1653; but it appears certain that he died in Red Lion Square, London, on April 9, 1709, and was buried in the parish church of Sprotborough, about three miles from Doncaster, Yorkshire. He thus lived through the reigns of Charles II, James II and William and Mary, and a part of that of Queen Anne. His father, the first Sir Godfrey, had been made a baronet soon after the restoration by Charles II, and when he died about 1684 his son succeeded to his title and estate, including Sprotborough Hall, then one of the stately homes of England, but now no longer standing. Of Copley's education and upbringing little is known, though he was admitted to Lincoln's Inn in 1674. Following in his father's footsteps, he served as member of Parliament, first for the little town of Aldborough and then for Thirsk, and was High