

by fluorocitrate were presented. In the discussion of arsenical inhibitors, emphasis was placed on the different actions of monosubstituted (for example, lewisite, mapharside) arsenicals, which inhibit pyruvate oxidation, and disubstituted (for example, diphenylchlorarsine) compounds which inhibit isocitric dehydrogenase, as well as on the practical application of 2,3-dimercaptopropanol in reversing the inhibition by arsenicals.

The organo-phosphorus inhibitors were discussed in relation to their action on cholinesterase, and to the reversing effect of pyridine-2-aldoxime methiodide. As an example of antimetabolites, Sir Rudolph discussed the antagonism of the effect of serotonin by 1-benzyl-2,5-dimethyl-serotonin.

F. Dickens (London) discussed the regulation of enzymic reactions within the cell with special reference to carbohydrate metabolism. Regulation can be provided by structural barriers within the cell, but also by enzymic mechanisms which do not require structural separation of reactants. Examples of the latter type are given by: (1) control of rate of mitochondrial respiration by the concentrations of inorganic phosphate and adenosine diphosphate; (2) 'feedback' by inhibition of the enzyme by the product of the reaction, for example, inhibition of hexokinase by glucose-6-phosphate; (3) the existence of different mechanisms for breakdown and synthesis, for example, the equilibrium of the uridine diphosphoglucose pathway of glycogen synthesis is much more favourable to synthesis than is the reversal of the phosphorylytic breakdown. Dickens directed attention to situations where the pentose phosphate pathway is particularly active in relation to glycolysis, for example, in the lactating mammary gland, where its function is probably to provide reduced triphosphopyridine nucleotide for fat synthesis, and in the lens where its function is possibly to provide the same compound to keep glutathione reduced.

H. Chantrenne (Brussels) concluded the conference by a discussion of the present status of the investigation of the mechanism of protein synthesis in general, and of enzyme synthesis in particular. He pointed out that the earlier sharp distinction between adaptive and constitutive enzymes has been abandoned. The recent work of Ingram on abnormal haemoglobins has shown that even the fine details of the protein structure are controlled by the gene. A mutation of a single gene causes a change of one amino-acid in the polypeptide chain. It is conceivable that the deoxyribonucleic acid of the gene contains the information which determines the sequence of amino-acids in the protein chain. This information must be transferred to the ribonucleic acid in the cytoplasm, where the protein is synthesized. The function of the inducer, the presence of which is necessary for formation of an enzyme, is not known. However, it has been shown that it acts in catalytic amounts, not autocatalytically. This suggests that it acts on an enzyme-synthesizing mechanism which is already present, perhaps in an inhibited form. In the discussion of this paper, Desnuelle pointed out that enzyme activity requires a specific configuration (tertiary structure) of the polypeptide chain. The native form of an enzyme is a unique, unstable structure among many more stable structures. It is, therefore, likely that not only the arrangement of the residues along the chains but also the specific folding of these chains are gene-controlled. This must be taken into account in any consideration of enzyme synthesis.

An unusual feature of this conference which had much to recommend it was that the programme called for only two speakers each day, one in the morning and one in the afternoon. This enabled the speakers to give a long introduction (about 45 min.) for the benefit of non-specialists, before a coffee or tea break, after which the speaker continued for a further 30-45 min. A discussion then followed.

E. C. SLATER

ENERGY TRANSFER WITH SPECIAL REFERENCE TO BIOLOGICAL SYSTEMS

THE mechanisms by which energy may be transferred from one atom or molecule to another have become a prominent theme of chemical kinetics, photochemistry and radiation physics—as well as of many biological processes. The same fundamental processes and many of the outstanding problems are common to each of these sciences, and those of biological systems, in particular, depend for their solution on development in other fields. The efficiency and generality of energy transfer between molecules has been fully appreciated only quite recently, and the discussion on this subject, which was held by the Faraday Society at the University of Nottingham during April 14-16, was one of those timely meetings for which the Society is noted. It was attended by two hundred physicists, chemists and biologists, about one-quarter of whom were from overseas.

The discussion was divided into two parts, the first concerned with energy transfer processes in general and the second with their occurrence in bio-

logical systems. After the president, Dr. E. W. R. Steacie, had welcomed the overseas visitors, the Spiers Memorial Lecture on "Transfer Mechanisms of Electronic Excitation" was delivered by Prof. Th. Förster, of the Technischen Hochschule, Stuttgart. This provided an excellent introduction to the first part of the discussion, which was concerned almost entirely with this topic. The transfer of electronic excitation energy from one molecule to another can be a very efficient process which may occur, not only at every encounter, but even over distances of 50 Å. or more. Apart from the 'trivial' process involving emission and re-absorption of light, this transfer can proceed by a radiationless mechanism known as resonance transfer, the interaction between the molecules being one of dipole-dipole coupling and not overlap of electron orbitals which is significant only at much smaller distances. The process is often also referred to as the Förster mechanism, and Prof. Förster gave a clear account of the quantitative theory which he, principally, has developed. He

discussed the application of the theory to forbidden transitions, transfer within one molecule and between like molecules, and pointed out that conditions for excitation energy transfer are very favourable in biological systems since Nature often prefers a high local concentration of absorbing matter.

The first four papers of the discussion were all concerned with electronically excited organic molecules. Prof. G. Porter and Dr. M. R. Wright (University of Sheffield) discussed processes of deactivation involving change of multiplicity. In particular, they presented rate constants for the decay of triplet states of aromatic molecules in solvents of varying viscosity and in the presence of paramagnetic molecules and ions and gave an interpretation of the latter process in terms of overall spin conservation rather than magnetic perturbation of spin-orbital coupling. Dr. A. Weller (Technischen Hochschule, Stuttgart) described his work on the reactions of excited singlet state molecules, with particular reference to acid-base equilibria and proton transfer in the excited state. Dr. B. Stevens (University of Sheffield), in the only paper dealing with the vapour phase, described experiments which showed that transfer of energy from electronically excited benzene to anthracene occurred over an average distance of 7.6 Å. Dr. E. J. Bowen (University of Oxford) described fluorescence studies of the excited singlet states of anthracene derivatives, with particular reference to the influence of temperature and solvent viscosity. The data indicate that two processes of radiationless conversion—probably to triplet and ground state—are operative.

There was much discussion following these papers, most of which was about radiationless transitions and particularly the effect of viscosity upon them. Prof. Porter had interpreted this effect in terms of different configurations of the two states, and Dr. Bowen's explanation involved the attainment of a certain amplitude of vibration. Prof. H. C. Longuet-Higgins (University of Cambridge) thought that it was the removal of energy by the solvent which was important and that the greater efficiency of solvents of low viscosity was a result of their having the lower-frequency components necessary for this transfer. Dr. D. H. Whiffen (University of Birmingham) suggested that it is molecular rotation which is important and that a time-dependent mixing of singlet and triplet states is introduced by interaction between rotation and spin-orbit coupling. Prof. J. D. Bernal (Birkbeck College, London) pointed out the importance of structure and the inadequacy of viscosity as a measure of microscopic properties—a point which was emphasized by other speakers. No general agreement was reached on these alternative theories in spite of the very valuable discussion.

The second scientific session began on the morning of April 15, with four papers on electronic energy transfer in solution. Dr. F. H. Brown, Dr. M. Furst and Prof. H. P. Kallman (New York University) gave an account of their extensive work on energy transfer in rigid and liquid organic scintillator systems induced both by light and by ionizing radiations. In these solutions as much as 10 per cent of the energy absorbed by the bulk material is emitted by the solute, and three mechanisms, in addition to the radiative one, are involved under various conditions. These are: (a) material diffusion transfer (in liquids only); (b) migration transfer; (c) single step transfer. Dr. J. B. Birks and K. N. Kuchela (University of Manchester) described similar studies in polystyrene

solutions as a function of wave-length. At concentrations greater than 10^{-4} molar the transfer was found to be non-radiative. Prof. M. Burton and H. Dreeskamp (Notre Dame University) described the measurement of luminescence decay times in scintillator systems by a method utilizing X-ray pulses of about 10 μ sec. duration and concluded that the measured decay times were characteristic of excitation transfer processes. Prof. M. Dole (Northwestern University, U.S.A.) and Dr. T. F. Williams (Atomic Energy Research Establishment, Harwell) described further studies of the disappearance of unsaturated linkages on γ irradiation of polyethylene, the high G value of which shows that energy transfer processes must be operative.

In the discussion on these papers, Prof. Kallman pointed out that the life-time of anthracene vapour molecules is shorter by an order of magnitude than that found in condensed phases, which Bowen suggested might be due to the fact that emission involves higher vibrational states of the excited gaseous molecule. Dr. Stevens said that the longer measured life-time in condensed media was probably due to re-absorption effects, a view shared by Birks, who emphasized that the 'molecular' life-time in condensed phases is as short as that found in the gas. Prof. Burton warned against over-confidence in values obtained by the phase-shift technique, since analysis of the data assumed an exponential decay which may not always be observed.

Dr. A. Szent-Györgyi introduced the papers on "Energy Migration in Biological Systems" with a summary of the various ideas that have been introduced in the past fifteen years: semiconductivity, resonance energy transfer and electron transport. Dr. Szent-Györgyi dealt more specifically with the electron flow in the respiratory chain and introduced a suggestion of his own, namely, that the partial charge transfer complexes that have been intensively studied during the past few years are the first steps in the one-electron oxidation processes that Michaelis first postulated.

These various aspects of energy transfer were dealt with in detail in the papers that followed: M. H. Cardew and Prof. D. D. Eley (University of Nottingham) reported measurements on the semiconductivity of amino-acids, haemoglobin and globin. Their findings of small conductivity with activation energies of the order of 3 eV. are in agreement with the values expected for a hydrogen-bonded CO...HN system. R. Mason (University College, London) described some possible instances of charge transfer in proteins, which have not yet found empirical foundation. Dr. G. Weber and F. J. W. Teale (University of Sheffield) reported on energy transfer in the haem proteins which results in the quenching of the tryptophan fluorescence of the native proteins and of the fluorescence of a conjugated group in haem-protein conjugates. The results, which are in general agreement with Förster's theory, permit some conclusions about the distribution of the haems on the surface of haemoglobin. A paper by Prof. Q. H. Gibson (University of Sheffield) described how haemoglobin formed from CO-haemoglobin by a light flash had a much greater reactivity towards carbon monoxide than the ordinary haemoglobin into which it reverted spontaneously with a rate of 200 sec^{-1} .

Four papers dealt with energy migration in photosynthesis. The background to the problems was presented by Prof. B. Rabinowitch and Dr. S. S. Brody (University of Illinois), who pointed out the

unique structural features of the chloroplast as revealed by the light and electron microscopes and the difficulty, if not the impossibility, of reproducing these features in our simple model systems. When the probable ways of energy migration in the chloroplast are considered the resonance transfer among some 200 chlorophyll molecules forming a photosynthetic unit appears the most likely. Prof. R. Lumry (University of Minnesota) presented work by himself, J. D. Spikes and B. Mayne in which simultaneous measurements of Hill reaction velocity and fluorescence yield were carried out. The parallelism of the two phenomena strongly favours the idea of a trapping centre to which the energy is transferred by resonance after its absorption by chlorophyll and where it is utilized in competition with the fluorescence and other radiationless deactivation processes. A paper by Dr. L. N. M. Duysens and J. Amesz (University of Leyden) dealt with the quantum requirements of diphosphopyridine nucleotide in photosynthesis. From this paper, as well as the previous work of Dr. Duysens on the oxidation of cytochromes, and from recent data that Prof. Britton Chance and T. Yonatan (University of Pennsylvania) presented in the course of the discussion, in which fast simultaneous recordings of cytochrome oxidation (by absorption) and diphosphopyridine nucleotide reduction (by fluorescence) were obtained, it appears now certain that the simultaneous oxidation of cytochromes and reduction of diphosphopyridine nucleotide are among the earliest events in photosynthesis. Prof. R. Livingston (University of Minnesota) and Prof. A. Terenin, E. Putzeike and I. Akimov (University of Leningrad) dealt with properties of isolated chlorophyll, namely, the quenching of the triplet state and the photoconductivity, respectively. Dr. W. A. Hagins (National Institutes of Health, Bethesda) and W. H. Jennings (Duke University, U.S.A.) presented experiments which showed the localization as opposed to migration of the excitation in the retinal rods, while M. J. Cowan, J. M. F. Drake and Dr. R. J. P. Williams (University of Oxford)

examined chelates of iron as models for the understanding of the variations in spectrum and redox potential of the cytochromes.

A paper by Prof. Britton Chance and E. L. Spencer (University of Pennsylvania), which described the rapid establishment of redox equilibria in the cytochromes of cells and cell particles at the temperature of liquid nitrogen, was interpreted by the authors as suggesting a solid-state mechanism of electron flow among the cytochromes.

Prof. D. E. Green (University of Wisconsin) concluded from the analysis of linked respiratory chain reactions that the electron transport is essentially a solid-state process occurring in a lipid phase; but the discussion that followed this paper showed that the evidence was not regarded as in any way conclusive.

In a discussion of energy in the biological systems, adenosine triphosphate could not be omitted. Although no paper dealt specifically with the properties of adenosine triphosphate, these were the subject of a lively discussion. Briefly, some speakers thought that adenosine triphosphate has had greatness thrown upon it by the accident of evolution, a distinction which may just as easily have fallen on its humble cousin pyrophosphate. Others believed that the rest of the molecule will be found to be indispensable in energy transfer. Prof. J. A. V. Butler (University of London) summarized the evidence for the first view. Dr. J. H. Turnbull (University of Birmingham) put forward the case for the latter.

The past twenty years have seen great improvements in the methods that reveal the purely structural features of biological systems. Because of their success we have come to look for explanations of biological events in terms of structural factors alone. The energetic aspect is equally important and indeed complementary to the structural, and this meeting rendered a good service to the biological sciences by bringing attention to this often neglected point.

G. PORTER
G. WEBER

HEATING BY ELECTRON BOMBARDMENT

ELECTRON bombardment heating is produced by accelerating electrons from a thermionic cathode on to a specimen, by means of a d.c. voltage. Simple focusing of the electron paths enables the heating to be highly localized and melting is achieved with very small power requirements. These facts, together with an ease of power control and the necessity for vacuum operation, explain the preference for heating by electron bombardment in some applications. Although used for very many years, it is only recently that this method of heating has become more widely known through its application to the melting of refractory metals for the purpose of floating-zone melting¹, welding^{2,3} and evaporation⁴. The growing interest in this technique was shown by the attendance of one hundred and sixty visitors, from British and overseas laboratories, at a symposium on "Electron Bombardment Floating-zone Melting and Allied Electron Bombardment Techniques", held at the Services Electronics Research Laboratory, Baldock, Herts, on March 10.

Several papers on electron bombardment floating-zone melting were given. In this method, a rod of the material being purified is held at both ends in a vertical position and a molten zone is induced in it by bombarding it with electrons from a circular cathode. The molten zone is held stable by surface tension and this imposes an upper limit⁵ on the maximum zone length, and hence diameter, of the specimen to be zoned. Relative longitudinal movement between the cathode and rod moves the zone along the rod and zone-refining takes place. The purified rod often becomes a single crystal. Metals sometimes out-gas violently when melting for the first time in a vacuum, and a bombardment-current controller^{6,7} is necessary to stabilize the current, which tends to fluctuate under these conditions. Whereas vacuum operation is advantageous when zoning reactive metals, it has the accompanying disadvantage that considerable material may be lost by evaporation. This has led most experimenters to use zone travel speeds which are too fast for segregation of impurities, and purifica-