nova in A.D. 1054, an estimated quantity amounting to about fifteen times the mass of the sun has been ejected. In such a case the material comes away with very high velocities. But Hoyle asks what would have happened had the original star been a binary.

Suppose the sun had at one time possessed a companion at about the distance of Jupiter, and suppose this companion became a nova. The ejected matter might not then come off with complete isotropy, so that the nucleus of the nova might have been knocked out of the system. When the outburst was dying down, some of the ejected matter may have had insufficient energy to escape from the gravitational field of the sun. This is Hoyle's suggested source of material for the formation of planets; the captured material need represent only a modest fraction, perhaps of the order of 10^{-4} , of the total ejected matter. The resultant angular momentum is regarded as traceable to the original orbital motion of the binary. However, the idea is so far only in tentative form; its author will no doubt shortly provide a fuller discussion.

Condensation Processes

Hitherto, gravitation has usually been thought of as the fundamental agency responsible for the condensation of nebulous matter into planetary bodies, either by causing a cloud of such matter to collapse upon itself under its own gravitation, or else by aiding accretion by causing particles of a cloud to fall towards an incipient planet passing through it. Jeffreys⁵ has, however, recently posed the crucial question as to whether gravitation is the only important agency in producing condensation. The commonest process of condensation with which we are familiar is that represented by a raindrop. Is it possible that this process plays a part in the formation of a planet? The actual form of the process would be more like that which occurs in the production of a snowflake, condensation being directly into the solid state. The only criterion as to whether it will take place is that the partial pressure in the surrounding gas should exceed the vapour pressure of the solid. The necessary figures for the vapour pressures of planetary matter in the solid state are difficult to come by; but Parson⁶ has given estimates according to which the criterion is likely to be satisfied at the kind of temperature to be encountered at, say, the distance of Jupiter even for existing pressures there.

The merit of such condensation as the key to the production of planetary material is that it can proceed in much less specialized conditions than the elaborations of the various theories are designed to provide. It is, in fact, fundamentally equivalent to an earlier suggestion by Lindblad⁴.

Some indication of the validity of these ideas may be found in the fact that there are in the solar system small bodies, the density of which is less than that of any known solid. Jeffreys's suggestion is that such a body may be a loose agglomeration of crystals which have grown by this process of condensation—that the body possesses, in fact, the structure of a large snowball.

REACTIONS AT INTERFACES AND THEIR SIGNIFICANCE IN BIOLOGY

By DR. J. F. DANIELLI

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IN his Liversidge Lecture before the Chemical Society, on "Reactions in Monolayers", Prof. E. K. Rideal made the most comprehensive survey yet available of studies of chemical reactions in monolayers. This is a field of chemistry which has recently become of exceptional interest to the biologist, so much so that the cell physiologist cannot afford to be ignorant of the progress which has been achieved in the last fifteen years; this is all the more remarkable in that thirty years ago this aspect of chemistry, practically speaking, did not exist.

It has, of course, for long been realized that reactions at interfaces present peculiar features, and that some of these may be of great importance in biology. F. G. Donnan laid emphasis on the importance of surfaces in biology when giving the first Liversidge Lecture. But before biologists could begin to consider these theoretical possibilities in relation to their special field it was requisite: first, that techniques should be devised capable of dealing with the surface properties of molecules of types of biological interest; and secondly, that an exploration should be made of the types of reaction and behaviour particularly characteristic of molecules at interfaces. The first of these steps was to a large degree accomplished by the early nineteen thirties, but the second phase was barely commenced. N. K. Adam had made some studies of hydrolysis of lactones in monolayers, and of the oxidation of cholesterol monolayers, which were highly suggestive. To-day a substantial part of the field has received a preliminary survey, largely embodied in reports from Prof. Rideal's own laboratory, and, though only parts of the field have been touched, it is already apparent that it will yield results of the greatest value to biologists.

From a theoretical point of view, the importance of this field is sufficiently emphasized if we consider some of the reactions involving the common major components of living tissues—fats, proteins, nucleotides and carbohydrates. The great majority of the natural fats are so insoluble in water that their reactivity as individual molecules in aqueous solution can be neglected. The final steps in their synthesis, and the initial steps in their utilization, must occur either in the interior of a lipid phase or at a lipid-water interface. The enzymes catalysing these reactions are insoluble in lipoids, so that the reaction site is limited to interfacial regions. The same is true of the steroids. The proteins are thought by some to be synthesized as polypeptide chains adsorbed at oil-water interfaces, and to acquire specific characteristics as globular proteins by processes occurring on desorption. Whether this be so or not, it is certain that a protein molecule, in the later stages of its synthesis, itself constitutes a moderately well-defined interface, in the vicinity of which any further synthetic or degradative reactions must occur. Finally, the enzymes catalysing the reactions affecting fats, steroids, proteins, nucleotides and carbohydrates are themselves such large molecules that the reactions they catalyse are in fact occurring at the surface of the enzymes, that is, at an enzyme-water interface, and in no sense in a homogeneous solution. In brief, it is fair to say that the present state of knowledge

¹ Von Weizsäcker, C. F., *Z. Astrophys.*, **22**, 319 (1944).

² Alfvén, H., *Stockholms Obs. Ann.*, **14**, No. 2 (1942); No. 5 (1943); *Nature*, **152**, 721 (1943). An account of the theory and of the difficulties in previous theories which it is designed to overcome is given by A. Hunter, *Nature*, **156**, 378 (1945).

³ Biermann, L., *Z. Astrophys.*, **22**, 4 (1943).

⁴ Lindblad, B., *Nature*, **135**, 133 (1935).

⁵ Jeffreys, H., *Nature*, **153**, 140 (1944).

⁶ Parson, A. L., *Nature*, **154**, 707 (1944).

indicates that the vast majority of the chemical reactions occurring *in vivo* are reactions occurring at interfaces, and moreover at interfaces resembling in type those which can be explored by present-day surface techniques.

That chemical equilibria at interfaces would be different from those in homogeneous solution was suggested by J. J. Thomson (1888), in his work "Application of Dynamics to Physics and Chemistry". Much attention has from time to time been devoted to the study of this principle, and H. Freundlich (1930), when giving the second Liversidge Lecture, brought together many striking examples of this phenomenon. We now know that interfacial regions differ from the homogeneous phases with which they are in contact in many particulars: the pH, ionic strength, oxidation-reduction potential and the ratio of univalent to polyvalent ions at an interface may all differ substantially from their values in the surrounding bulk phases. In addition to these differences, molecules diffusing into the interface will often be subject to special forces produced by the orientation of molecules at the interface, as a result of which unusual concentrations and juxtapositions of particular chemical groupings may arise, and to a sharp electrical potential gradient in the interfacial region produced by the oriented polar groups of the interfacial molecules. Some of the effects of these peculiarities of interfaces may be demonstrated by very simple experiments. Deutsch (1929) showed that if an aqueous solution of a pH indicator is shaken with a little liquid hydrocarbon, a marked colour change will occur if the pH of the aqueous solution is in the region in which the indicator is sensitive. The colour change produced by shaking is caused by adsorption of indicator on to the surface of the emulsified hydrocarbon, and is quite reversible, the original colour returning as the emulsion breaks. The change in colour on adsorption is produced by a shift in chemical equilibrium subsequent to adsorption. Later studies have shown that the shift is mainly caused by the fact that the pH in an interfacial region differs from that in the surrounding bulk phases. The colour shift shown by this experiment of Deutsch is in some ways allied to what is commonly known as the 'protein error' with pH indicators. When pH indicators are added to aqueous solutions of proteins, the colour produced may indicate a pH differing by more than a pH unit from the true value, given by a glass electrode. This 'error' has been shown to be produced, in part at least, by the fact that the pH at the surface of a protein molecule is substantially different from that of the bulk aqueous phase in which the protein is dissolved. When the indicator is adsorbed, it of course tends to react to the interfacial pH, not to the bulk pH.

A similar displacement of equilibrium is observed if a monolayer of palmitic acid is spread upon a solution of sodium and calcium acetate. If the sodium : calcium ratio in the acetate solution is 100 : 1, we might perhaps expect to find a similar ratio in the monolayer. But when the monolayer is swept off the solution and analysed, it is found that there is rather more calcium than sodium in the monolayer! This phenomenon lies behind the efficiency of calcium as an antagonist of the detergent action of soaps, and is likely to be concerned in determining the so-called 'physiological ratio' of sodium to calcium. For normal physiological behaviour of a tissue it is usually necessary that the

fluid bathing it should have a sodium : calcium ratio of the order of 100 : 1. That one calcium ion should be competent to balance the action of a hundred sodium ions is inconceivable; but if, as we now believe, the site of action of the ions is a surface, and at this surface rough equality of concentration and balance of action of sodium and calcium is produced by a bulk ratio of 100 : 1, then we have a reasonable explanation of the importance of the physiological ratio of this order.

Experiments such as those just mentioned are not those with which Prof. Rideal was particularly concerned, but formed part of the background of less specific factors against which the review of more specific factors given in his lecture must be viewed. By using the special techniques of surface chemistry, he and his colleagues have been able to study many details of behaviour of the molecules which are more permanently fixed at an interface. For example, it has been shown that the velocity with which a molecule in a monolayer will react with a constituent of the bulk solution is a function of the closeness of packing of the molecules; the closer the molecules are together, the more slowly they react with the bulk phase component. This is true of the hydrolysis of lactones and esters by hydroxyl ions, and of the oxidation of unsaturated fatty acids by acid permanganate solution. Compression of a monolayer of such substances affects the rate of reaction by changing both the energy of activation and the steric factor, as may be shown by the case of the hydrolysis of trilaurin by hydroxyl ions: when the surface pressure, that is, the force compressing the monolayer in the two dimensions of the surface, is raised from 5.4 to 16.2 dynes/cm., the activation energy is raised from 10,100 to 15,100 calories, while the steric factor increases from 1.1×10^{-6} to 4.1×10^{-2} . The velocity of hydrolysis of esters in monolayers is also affected by the orientation of the different parts of a molecule with respect to one another. Cetyl palmitate takes up one type of configuration giving a velocity constant of 0.18 min.⁻¹ under a given set of conditions, whereas ethyl palmitate, taking up a quite different configuration at an interface, has a velocity constant under the same conditions of 0.005 min.⁻¹. Prof. Rideal points out that there is some degree of parallelism between the phenomena observed when esters in monolayers are hydrolysed by hydroxyl ions, and those observed when the enzymelipase is the catalytic agent. It would be of great interest to see such studies extended, though a pre-condition for analysis of the enzyme studies may perhaps be the isolation of pure lipase, which has not yet been achieved. But even the present state of investigation is of interest and assistance to the biologist in the formulation of working hypotheses concerning the control of enzymic reactions. One of the central problems of the cell physiologist is to discover the mechanisms whereby the rates of enzymic reactions are adjusted to suit the needs of the organism. It is common for enzyme and substrate to exist in the same cell, apparently in close proximity, and yet no net reaction will proceed until a particular phase of physiological activity is embarked upon. The influence of surface pressure on reaction velocity indicates one means whereby a reaction may be held in abeyance until required.

Another phenomenon of great interest to biologists is the formation of molecular complexes between molecular types such as fats, steroids, phospho-lipins, proteins and lytic molecules. Monolayer techniques

form an unusually elegant means of studying these complexes. When a second substance is injected into the aqueous solution underlying a monolayer of a pure substance, a large increase in surface pressure is found if complex formation occurs accompanied by penetration of the second molecular species into the monolayer. If the reaction is between polar groups only of the two molecular species, there may be no change of surface pressure, but there will be a change in the electrical potential across the film. If there is no complex formation of any type, no change in either surface pressure or potential occurs. Complex formation of the type revealed by these surface techniques has been shown to be of importance in the mechanism of red cell lysis, and in the permeation of some membranes by such substances as phenols. For example, the penetration of hexyl resorcinol into *Ascaris lumbricoides*, according to Trim and Alexander, may be accelerated by a factor of about fourfold by adding low concentrations of detergents, with which the resorcinol forms complexes. The mechanism of this acceleration is not yet understood, and may well repay detailed study.

Interesting complexes are formed between some carotenoids and certain proteins. Astaxanthin exists in the eggs and integument of lobsters, crabs, etc., as a blue-green pigment. The carotenoid is readily oxidized to astacene in the dead animals. When the association between carotenoid and specific protein breaks down, a colour-change ensues. The association may be destroyed by boiling, which denatures the specific protein, or by addition of sodium soaps. In

the latter case, the change is reversible, restoration of the original complex being achieved by addition of calcium (Peters and Wakelin). Visual purple also appears to be a complex of this type, namely, protein-carotenoid. One theory of the action of light upon visual purple is that it oxidizes a terminal CHO group of a polyene chain to the corresponding aldehyde. Monolayer studies show that on conversion of a CHO group to a CO group, a large change of surface potential occurs. It is therefore possible that, if the carotenoid of visual purple also forms part of the lipid layer of the cell membrane, the photo-oxidation will produce a change in surface potential sufficient to cause electrical excitation of the cell. These relationships are at present all highly speculative, but it is in harmony with recent developments in cell physiology to adopt the working hypothesis that the stimulation of retinal cells by light is produced by a surface photo-oxidation of the visual pigment incorporated in the cell membrane, and that the change in surface potential produced by this reaction temporarily discharges the resting potential of the cell, causing an electrical response.

These reflexions on the topics of Prof. Rideal's lecture show that a pathway for investigation of many biological problems has already been secured by the study of reactions at interfaces. So numerous are these possibilities that the rate of investigation of these fields is likely in the immediate future to be determined almost entirely by the number of investigators available; all such investigators will find a source of inspiration in Prof. Rideal's lecture.

OBITUARIES

Prof. Ernest Shearer

A NATIVE of the island of Stromness in Orkney, Ernest Shearer was brought up to farming; but he could also sail a boat and follow the maritime pursuits of his Viking ancestry. A 'lad of parts', he was thoroughly schooled in mathematics and classics and went on to the University of Edinburgh where, between 1897 and 1904, he studied and graduated M.A. with honours in economics and B.Sc. in agriculture. His first appointment was to the Indian Agricultural Service, where in five years he reached the grade of assistant inspector-general. In 1911 he was appointed under the Egyptian Government as principal of the Giza Higher College of Agriculture and in 1919 he was made chief technical officer in the Egyptian Ministry of Agriculture.

In 1924 Shearer accepted the post of principal in the Edinburgh and East of Scotland Agricultural College; two years later he was made professor of agriculture in the University, thus becoming the first head of the Edinburgh School of Agriculture. During his tenure of office the proper utilization of land and the teaching of young farmers became more and more of national importance, and he rose to eminence as an authority on agricultural education. He reached this position by reason of his training and experience, but also because of inclination, for he had a great interest in, and sympathy for, young people. When he retired from his academic posts in the autumn of 1944 he became secretary to the Mid and East Lothian Agricultural Executive Committees, and thus continued to serve the farming community until the time of his death.

Shearer was a large and genial man, entirely free from affectation, with a strong sense of humour and great personal charm. Completely at ease in any situation, he would pass an hour as happily with his gardener as with his fellows on the Senate. He handled a brilliant pen and possessed great strength of character and determination. Not only was he thus well qualified for leadership but he could also be relied on to fight for any right cause and to stand like a bulwark in the interests of his people.

His hobby was the propagation of fine fruits and beautiful flowers. He had planned to retire to his beloved Orkney and to devote himself to the production of plants which would bring both amenities and profit to the island farmers. His untimely death is, therefore, as much a loss to his native land as it is a grievous blow to his friends and colleagues.

J. A. MORE.

Mr. L. E. Adams

LIONEL ERNEST ADAMS, who was well known to an earlier generation as an active and enthusiastic observer of the natural history of the British Isles, died at Ryde, Isle of Wight, on September 20, at the age of ninety.

Adams was the nephew of Henry and Arthur Adams, famous in their day for their researches on the molluscs, and joint authors of "The Genera of Recent Mollusca". Circumstances did not allow him to follow his uncles' wider sweep, and he had to confine himself to the British land and freshwater species, on which he became an authority of repute.