PHYSICS OF SOCIAL EQUILIBRIUM

THE paper read by Dr. R. Fürth, reader in theoretical physics in Birkbeck College, London, on August 15 at the Edinburgh meeting of the British Association under this title broke new ground, and the enterprise of the author is a welcome sign that the natural scientist is making even more strenuous endeavours than he has done in the past to apply the concepts he has developed to social problems. A large amount of the work which has been carried out in the 'natural' and 'social' worlds has always been of common interest to both, as, for example, the theories of evolution developed during the nineteenth century. Nothing but good can come from the sharing of ideas and co-operative endeavour, provided that there is a clear understanding that there are fundamental differences between, as it were, the 'climates' of the two worlds, and that what is useful and will prosper in one world will not necessarily survive in the other.

At the beginning of his paper, Dr. Fürth has underlined the dangers that beset us when this proviso is neglected. As he points out, the use of physical models for the understanding of social phenomena has often led to gross over-simplifications, and sometimes to disastrous misunderstandings. Examples cited in the paper include the familiar analogies which are drawn between the concepts of 'forces', 'balances' and 'equilibrium', which refer to the properties of solid structures, and the behaviour of social communities. The model of a rigid body is, in fact, often used in popular literature to explain the processes of social change. Expressions such as 'the swing of the political pendulum' have crept into everyday language, and the result, as Dr. Fürth points out, is to give the ordinary citizen the erroneous belief that "present difficulties will in due course resolve themselves automatically by the working of some miraculous social mechanism".

Dr. Fürth is, of course, correct when he finds the distinction between mechanical machines and social communities in the *voluntary* working of the latter, and in the *intelligent* co-operation which exists between its parts. But he tends to over-state his case when he argues that the use of statistical techniques in the analysis of human behaviour may tend to predictions that are "completely wrong". It is perfectly just to point out that "the fate of the spinning ball is in no way influenced by the results of previous games", and to argue that predictions of social, as contrasted with natural, events are often invalidated by the mere fact that they have been communicated to the persons whose behaviour was the subject of the experiment. But in this case the statistician's 'other things' are not 'equal', and the validity of statistical techniques is left unimpaired. Indeed, the value of prediction in the social field often lies in the fact that processes of social change can be set in motion to avoid the occurrence of such phenomena as population decline that would otherwise take place.

Dr. Fürth's criticism of statistical techniques is, surely, only valid if the end-product of social science is accepted as the understanding of the very purposes of human life itself, and few social scientists would be presumptuous enough to maintain anything so outrageously ambitious. The main achievements of social scientists during the past generation have been to demonstrate that the extent to which human society is, in fact, 'voluntary' and human co-operation 'intelligent', is very much less than the intelligent Victorian believed or the common-sense man of to-day assumes. It is the unconscious influences that determine our everyday behaviour, and the undirected processes that shape the structure and development of human societies, to which we are turning our attention in increasing degree, and it is in that area of human experience that the methods of the natural sciences are most directly applicable. To what extent the unconscious can and should be made conscious, and the undirected brought under control, remains to be seen. But much (perhaps everything) that makes for human survival depends on it.

Dr. Fürth ends his paper with a plea for the application of statistical mechanics, the branch of theoretical physics which has been developed for the theoretical treatment of many physical phenomena, to the problems of social organization. In so far as the principal field of application, as Dr. Fürth points out, has been to the physics of systems or 'assemblies' of very large numbers of identical particles, there is a strong probability that social scientists will find in this branch of knowledge a valuable means for unravelling the very baffling problems which arise from the interaction between the individuals which compose a social group or community. But to argue more than this at the present time is highly misleading. To compare (as Dr. Fürth does) the behaviour of 'communities' of crystals of pure substances with that of human societies is surely to create the confusions and encourage the errors which he so rightly deplores at the beginning of his paper. To ascribe the political stability of the United Kingdom and of the British Commonwealth of Nations to "the soundness of their structures on the physical principles of strength of material bodies" is, at least, a gross over-simplification. The value of "statistical mechanics" for the social scientist must first be demonstrated by painstaking experiment in the factory working group or the housing estate neighbourhood before such generalizations are permissible.

T. S. SIMEY

FIELD-WORK IN ZOOLOGY

A DISCUSSION on "Zoology at the Marine, Freshwater and Field Stations" was held in Section D (Zoology) of the British Association at Edinburgh on the morning of August 13. Mr. E. Ford, director of the Marine Station at Millport, opened the discussion by describing the development of marine stations in Great Britain and abroad. His own station at Millport had as its first home the *Ark*, originally a floating laboratory moored in a submerged quarry at Granton, Edinburgh. Whereas in former days the attitude was that of the general practitioner in the broad field of zoological inquiry, the present tendency is to think and work as specialists. Specialization not only canalizes aim and effort but also leads almost inevitably to specialized institutions. The majority of the stations in Great Britain were at first committed by constitution to study the life of fishes in the interests of British commercial fisheries.

To-day, however, the main responsibility for this highly important public service is exercised directly by the Government through its different fishery laboratories and its permanent boards and commissions. There are special staffs and special laboratories dealing with other aspects. The Oceanographic Laboratory in Edinburgh, engaged in a plankton survey by means of automatic plankton recorders towed behind commercial ships; the newly constituted National Institute of Oceanography, devoting special attention to marine physical science; and the new Institute of Seaweed Research were quoted as examples.

Mr. Ford believes that there is a limit to the size of the station, beyond which it begins to lose that priceless opportunity for close personal association between all within its walls. A station that is too small has limited activities; a station that is too large is an impersonal workshop, and not a meeting place for colleagues.

Dr. H. D. Slack described the field laboratory on the west shore of Loch Lomond which was established in 1946 by the Zoology Department of the University of Glasgow for the study of life in fresh water and of insect life on land. This, being purely an extension of the Department of Zoology, has the same dual role of research and teaching. In the undergraduate course during the summer term, the benthic fauna of the Loch along a transect from the shore forms a part of the practical work, together with methods of hydrological investigation and a study of the plankton. Students specializing in freshwater biology undertake a research problem for presentation as a thesis in their honours degree examination.

Loch Lomond is divided into two by the Highland Boundary Fault: a shallow southern portion not more than 30 metres deep on Lower Carboniferous and Devonian rocks, and a long and narrow northern part on Cambrian mica-schists and grits with a greatest depth of more than 200 metres. Preliminary investigations of the hydrological data show that a thermal stratification is established in the deeper portion in July, but not in the shallow portion. The Loch is in general oligotrophic in character, but less so in its southern than its northern half. How far this tallies with the distribution and quality of the fauna has still to be determined, for very few observations have been made on the fauna of the deeper waters. Perhaps the distribution of fishes may afford evidence of the Loch's differential evolution. A perch – pike stage has been reached in the lower loch, and roach are common below the Highland Boundary Fault, while brown trout are still numerous throughout the Loch and appear to be more so toward the northern end. Only a reference in an old statistical account of 1796 stands as evidence of char having once been present, but the powan (*Coregonus clupeoides*) is abundant. This fish lives for the most part in deep water, feeding on pelagic plankton, but appears in large shoals in littoral regions during the summer.

Prof. L. A. Harvey's paper on field zoology at Exeter was read for him in his absence by Mr. J. Delany. He described the development of an annual course on ecology organized as a fortnight's camp under canvas. This started with only two students in 1932, was thrown open to the Universities of Britain in 1935, and now accommodates up to thirty students with a staff of three or four teaching members. Ladram Bay near Sidmouth was selected as a site from which ready access to as wide a variety of habitats as possible could be had. The programme is varied each year according to the interests and needs of the students and also of the staff. But whatever the individual items, the major aim has been to teach the principles and practice of ecological investigation rather than merely to elucidate the ecological relations within any given habitat. Quantitative methods used include ½-m. sq. transects on the shore and salt-marsh and on moorland and bog, the use of random squares for assessing, in particular, plant populations, methods of estimating hardness, salinity, oxygen content, pH of water and various methods of trapping small mammals and of estimating the vegetation pattern associated with their distribution. Special techniques have been used at different times for assessing grasshopper populations, quantitative scoops for mud and gravel communities in the River Otter and the like.

Prof. Harvey, after brief mention of a fortnight's course of field studies for teachers which continued for some years but is no longer arranged, described a third project, namely, the investigation of the ecology of Lundy Island in the Bristol Channel. The Lundy Field Society has been founded, membership of which is open to anyone interested, and by this means it is proposed to weld together the interests and activities of both professional biologists and amateur naturalists. So far this has been most successful on the ornithological side, and an ornithologist is maintained as warden. Considerable progress has been made on surveys of the shores of the Island. Here, within a very small compass, exists a high degree of variation—from extreme exposure on the granite of the west and south-west to full shelter on the east, while entirely different shore conformations are provided by the little tag of slate at the south-eastern tip.

Dr. J. P. Harding, in expressing a museum attitude to work at marine, freshwater and field stations, said that there are many problems in zoology which can be best attacked by uniting the efforts of workers in many different fields. Among the most important are those concerning the mechanisms of evolution and the origins of species. The museum worker has helped with these problems not only by naming, describing and classifying species, but also by studying their geographical distribution. Animals living at any one time in a small area such as the British Isles can be divided into a number of quite different species. Each species consists of a population of individuals distinguished from other species by the possession of a number of characters which, while they will vary to a greater or lesser extent from individual to individual, do not do so sufficiently for there to be any overlap between one species and the next. Over a large area, however, such as that of a continent, the population living at one end may be quite distinct from that at the other; but there may be a complete series of intermediate populations in between. The herring gull and the lesser black-backed gull provide a very good example. These behave in Great Britain as two quite distinct species with no intermediates; yet a continuous series of birds linking up the two can be found by studying these gulls throughout their geographical ranges. Herring gulls extend in North America from Labrador to Alaska, and lesser black-backed gulls in Europe from Norway to Siberia. The birds in Siberia are, however, very much more like the herring gulls of Alaska than the lesser black-backed gulls of Britain, although they are linked with the latter by a more-or-less continuous population. This is an extreme case of a continuously varying species, the end members overlapping but not inter-breeding.

The museum man with large collections of specimens from all over the world is in a favourable position for studying this type of geographical distribution; but it is the field-worker who can best study local variations of physiological characters, and these, being more intimately concerned with the animals' welfare, are often of great adaptive value. The museum worker is constantly finding differences between his specimens and being unable to decide whether these are due to the effects of the environment or not; only someone in the field can find out for him.

The president of Section D (Dr. C. F. A. Pantin), Mr. J. Colman, Mr. H. C. Gilson, Prof. H. R. Hewer, Prof. A. D. Hobson and Dr. C. F. Hickling took part in the discussion which followed. Dr. Pantin drew a distinction between biology and the physical sciences; workers in either research or teaching in biology have to derive general principles from very complex situations. The solution of biological problems, he said, often comes from unexpected directions, and can only be appreciated by those with a direct contact with the animals themselves.

TRANSFER OF LIGHT ENERGY WITHIN THE PIGMENT SYSTEMS PRESENT IN PHOTOSYNTHESIZING CELLS

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IN investigations[1,2] on photosynthesis of diatoms, it was found that light quanta absorbed by the carotenoid fucoxanthin brought about as strong a fluorescence of chlorophyll *a* as light absorbed by chlorophyll *a* itself; thus, energy transfer occurs with an efficiency of one hundred per cent.

With more refined spectral methods, we have carried out a more general investigation of the energy transfer between pigments within the photosynthetic apparatus. The work covers the main groups of photosynthesizing organisms. Fluorescence spectra were determined by means of a monochromator and a slightly modified photoelectric A.C. amplifier as described by Milatz and Bloembergen[3]. Various wave-lengths of incident monochromatic light were used for exciting fluorescence; the absorption of the incident light in the cells was also determined. Action spectra of photosynthesis of the same organisms were determined by J. C. Goedheer in this Laboratory, using a polarographic method[4]. In some cases phototaxis action spectra, which may be assumed to correspond with the photosynthesis action spectra[5,6], have been measured with Manten's bacteriophotometer[5].

The main photosynthetic pigment in purple bacteria, bacteriochlorophyll, probably occurs in three distinct bacteriochlorophyll-proteins[7], distinguished by absorption maxima at 800, 850 and 890 mμ respectively. For the sake of convenience they will be called here *B* 800, *B* 850 and *B* 890.

By examining fluorescence spectra, it was found that only *B* 890 shows fluorescence.

Transfer of light energy from the carotenoids to *B* 890 was found to occur in *Chromatium* strain *D* and in a strain of *Rhodospirillum molischianum* with efficiencies of 35–40 and 50 per cent respectively. If complete transfer to *B* 890 occurred, the fluorescence action spectrum (corrected for absorption) would be proportional to the absorption spectrum of the bacteria, also between 450 and 550 mμ, in which region the absorption is mainly due to the carotenoids. If, on the other hand, no energy transfer to *B* 890 occurred, the fluorescence action spectrum would be proportional to the absorption spectrum of bacteriochlorophyll, and only a small activity for fluorescence excitation would be found between 450 and 550 mμ. The fluorescence action spectrum actually found (Fig. 1) proves that a partial transfer takes place. Fig. 1 further shows that the action spectrum for *B* 890-fluorescence is proportional to the action-spectrum for phototaxis (or photosynthesis). This indicates that the carotenoids take part in photosynthesis only by transferring their excitation energy to *B* 890.

Additional experiments in the infra-red region showed that *B* 800 and probably *B* 850 also transfer their excitation energy to *B* 890.

By determining fluorescence spectra for various wave-lengths of incident light, it was found that, in vital cultures of *Chlorella*, only chlorophyll *a* shows fluorescence. From the fluorescence action spectrum it could be concluded, in an analogous way as above, that an almost complete transfer of excitation energy from chlorophyll *b* to chlorophyll *a* occurs, which is in agreement with the high efficiency of chlorophyll *b* in photosynthesis.

In solutions of about 10^{-3} *M* of both pigments in acetone, transfer of energy from chlorophyll *b* to *a* was also established, the efficiency being about 50 per cent.

The rather complicated fluorescence spectra of the red algæ *Porphyra lacineata* and *Porphyridium cruentum* and also of the blue alga *Oscillatoria* sp. could be analysed reasonably well in terms of fluorescence spectra of chlorophyll *a*, of the phycobilins and of an unknown pigment with a fluorescence maximum at about 725 mμ.

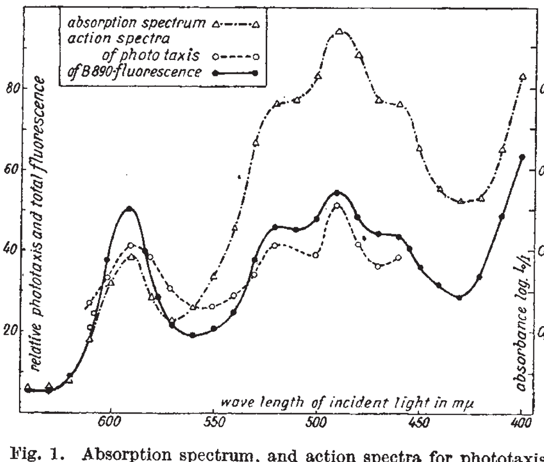

Fig. 1. Absorption spectrum, and action spectra for phototaxis and for *B* 890-fluorescence of *Chromatium* strain *D*. The absorption peak at 590 mμ is due to bacteriochlorophyll, the absorption between 450 and 550 mμ mainly to carotenoids. The carotenoids appear to be active with about the same efficiency both for phototaxis and for bacteriochlorophyll fluorescence. The fluorescence molecule is *B* 890 (see text)