translating each with the aid of the appropriate compiler. Thus, in our example, the supervisor arranges for the translation of the user's program from FORTRAN to machine language and initiates its execution (instruction I), makes a copy of the original program (instruction II—as when the IBM 7090 FORTRAN system gives the user a "listing" of his program), and (in a hypothetical world in which computer software is free to spread vegetatively through a receptive network of inter-compatible computers) dumps the entire computational output into a virgin computer of the same make (instruction III).

We shall not spend much thought on the computational analogy of infection in the world of computers. This kind of trick can be played by any computer programmer who possesses sufficient knowledge of the superviser and sufficient disregard of the sanitary rules which discourage users from deliberately "over-writing the system". To the extent that these rules are incorporated into the system software itself, the rogue programmer's intent to subvert must be backed by additional knowledge and ingenuity if he is to succeed. The point we wish to emphasize here—indeed the point towards which our entire argument is oriented—is that this *segregation of user's software and system's software* has evolved among computer users for sanitary and economic reasons, and that, as Weismann first noted, a similar segregation of germ plasm (DNA specifications) and soma (cellular machinery of implementation) has evolved naturally. If we merely want a program capable of causing its own replication, in addition to its other action, why do we not use simple self-reference, as follows:

1. Do this and that.
2. Copy the whole of this message on to a fresh sheet of paper and pass both copies on to other people.

We propose that the operational objections to this are similar in the biological and the computational cases. The reason why computer scientists do not in general encourage the user to write a program which will (*a*) act on itself or (*b*) modify the superviser during execution, arises from considerations of public order: if such transgression of boundaries were allowed difficulties would be created for the same or other users of the same program, or of other programs using the same superviser. The penalty of having a relatively invariant somatic apparatus is the hazard of subversion by agencies able to exploit this invariant structure. That the penalty has been found worth paying in both contexts is possibly not coincidental. The analogy seems sufficiently striking to bear further investigation.

* Substance of a talk delivered at an international symposium on "Biological Theory" held at Bellagio, Italy, August 1966.

# A DECADE IN ANTARCTICA

By DR. MARTIN HOLDGATE
The Nature Conservancy

ANTARCTIC research has sometimes been compared with space research—or more particularly, lunar research—because the region under study is in both cases so inhospitable that the scientist has to make elaborate provision for his own biological needs before he is able to turn to his professional tasks. Even if the comparison is far fetched the result is to make Antarctic and space research alike expensive per unit of knowledge gained. To maintain fifty scientists—most of them junior post-graduates—in the Antarctic currently costs Britain a little under one million pounds per annum, which is several times the average for university workers at home. And Britain is unusually efficient in maintaining a high output of Antarctic science per unit of expenditure: many national programmes have far less to show for their money.

In the past decade, nations, men and money have become involved in Antarctic research on an unprecedented scale. Before 1944, the continent and surrounding oceans were explored only by periodic expeditions, designed as carefully organized raiding parties, which descended at a chosen landfall to spend a few months or years gathering as much as they could before retiring to the temperate zones to assimilate it. Between 1944 and 1956 permanent stations, with wintering personnel, were established at several points especially on the Antarctic Peninsula, but too many of these stations became embroiled in disputes over sovereignty and were located primarily so as to strengthen territorial claims and only secondarily to undertake research. Only in 1955–56, with the development of the large international programme called for by the I.C.S.U. Special Committee for the International Geophysical Year (C.S.A.G.I.), did scientific research emerge unquestioned as the dominant activity on the lands south of 60° south latitude.

A periodic stocktaking is desirable in enterprises of this kind. In 1966 ten years of international scientific effort in the Antarctic are being celebrated by the observance of an "Antarctic Week" in all the twelve nations represented on the I.C.S.U. Scientific Committee for Antarctic Research (SCAR). It is an appropriate moment for reappraisal, justification and forward planning.

During the past decade the greater part of Antarctica has been seen and extensive traverses over snow and aircraft flights have extended survey work so widely that the main geographical features, and broad relief and contouring of the whole continent are now established. Under the guidance of the Working Group in Cartography of SCAR, internationally agreed guide lines are being adopted to ensure uniformity of sheet sizes and symbols in the maps being produced by national survey centres. Seismic techniques, reinforced by gravimetry and most recently by tractor and airborne radio echo sounding apparatus, have revealed the main characters of the Antarctic ice cap. It has proved to have a far greater thickness (averaging around 2,000 m) than was suspected before the IGY, and to obscure deep surface canyons and inland drainage basins.

The mass balance of the ice cap—which contains 95 per cent of the world's ice, influences climate widely over the southern hemisphere, and may affect seismic activity across the southern rim of the Pacific—is being studied by increasingly sophisticated techniques. The structure of the ocean floors about Antarctica is being determined by sea-borne gravimeters and magnetometers and by seismic traverses. Since 1955, geological knowledge has advanced so greatly that 76 contributors from all the nations now active in the south took part in a symposium organized by SCAR in 1963. The history, stratigraphy and palaeontology of both eastern and western Antarctica, the one an ancient, massive block of Archaean crystalline rocks overlain by Palaeozoic sediments and volcanics and affected by three or four early orogenic episodes, and the other a fringing archipelago of younger rocks elevated and tilted intermittently since the Cretaceous, have been described in moderate detail. Absolute age determinations, reinforced by stratigraphy and palaeontology, have set a time-scale to the main episodes, and clarified the oscillations of the ice cap in past epochs. The involvement of Antarctica in continental drift, and its structural relationships with other southern land masses, has been clarified.

Above the Antarctic, the past decade has seen the substitution of a reasonably detailed picture of atmospheric circulation in both stratosphere and trophosphere for an earlier fragmentary and tentative series of inferences. A synoptic network of surface and upper atmosphere observatories, set up for the IGY, has been operated continuously for a decade. And since 1957 weather analyses over the Antarctic continent and southern hemisphere have been made on an international basis at an International Antarctic Analysis Centre in Melbourne. Auroral, ionospheric, cosmic ray and other geophysical studies have made great advances, especially where bi-polar comparisons have been undertaken. The recent IQSY programme, in conjunction with earlier IGY results, will undoubtedly stimulate ionospheric physicists to new and more advanced activities in the region.

Oceanography and biology are among traditional Antarctic sciences, and the former especially received much emphasis between 1920 and 1940. Neither was much involved in the upsurge of Antarctic research in the IGY, but since 1960 land based biology has itself gone through a period of expansion and breakthrough. The terrestrial and freshwater ecosystems, comprising small and inconspicuous organisms drawn from only a few species, but occurring in great numbers of individuals, have received critical attention. Vegetation has been described, and the adaptations of plants and invertebrates to an environment with widely fluctuating temperatures and low water availability are now being explored in an increasingly sophisticated way. The marine birds and mammals—traditional research topics for Antarctic biologists—are now the subject of specialized ethological, physiological and population studies. The Antarctic ocean, with its high standing crop of plankton on which almost all the food chains in the region ultimately depend, is receiving increasing attention and the past decade has seen the proliferation of work on the inshore benthos by free diving techniques as well as more traditional methods. A SCAR Symposium on Antarctic Biology was held in 1962, and one on Oceanography in September 1966, both bringing together a wide range of specialists and forecasting future developments in these fields.

In all these sciences, an impressive record of achievement since 1956 is rendered the more valuable by the high degree of international co-operation that has been reached. SCAR, as a forum for the scientists of all Antarctic nations, has been both small enough and practical enough to conduct discussions relevant to the needs of the actual field scientist. International exchanges in the Antarctic have been backed up by visits and a flow of data between home countries. The permanent Working Groups of SCAR have maintained standing programmes in which the current needs in their sciences are highlighted, and have organized symposia for review and planning. A most impressive achievement in the biological field has been the preparation and submission to governments of agreed proposals for the conservation of flora, fauna and key habitats, and these proposals have now been embodied by the representatives of the contracting parties to The Antarctic Treaty in Agreed Measures passing into law in the various signatory countries. To have such unified measures, based on internationally agreed scientific advice, adopted to protect the wildlife of a whole continent and safeguard long-term research sites is a valuable precedent which could with advantage be followed in more contentious regions.

This example emphasizes two final points. First, Antarctica, with its difficult terrain and climate, has posed problems so great that scientists of many nations must participate in their solution. Scientists working in the south have demonstrated that such problems—and by inference, others of worldwide concern and importance—can be overcome once international agreement is reached on a broad programme, and sufficient men and material are made available.

Secondly, governments have found that such inter-

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# BOOK REVIEWS

## WYTHAM WOODS

### The Pattern of Animal Communities

By Charles S. Elton. Pp. 432+87 plates. (London: Methuen and Co., Ltd.; New York: John Wiley and Sons, Inc., 1966.) 90*s*. net.

The work that is the basis of this book began, as is mentioned in the preface, in 1942. Centred in the Bureau of Animal Populations at Oxford and organized as the Wytham Ecological Survey, it has stimulated, through the years, a continuous stream of specialist papers on ecological work done in the Wytham Woods estate of the University of Oxford. The survey has, of course, dealt mainly with the terrestrial environment and this is essentially what the book is about. The discussions are not confined to the state of affairs in Wytham Woods but the theoretical ideas propounded in the book rest on work done there by Elton and his colleagues. It remains to be seen whether Elton's ideas can usefully be applied to some of the conditions under which animals live in the terrestrial environment in the tropics and in other habitats.

Elton revolts against the classification of animal habitats, in the terrestrial environment, on the basis of the botanical community of the habitat expressed in terms of lists of plant species. This is because the individual animals move around in their environment in the usual three dimensions of space and in time. His classification of habitats is essentially an attempt to define the recognizable parts of the total available environment within which an animal species, or association of species, lives.

Seven "habitat systems" are defined, one of which is the "terrestrial system" on which the book concentrates. Systems are divided into "formation-types" of which "open ground", "field type", "scrub" and "woodland" are, apparently, sufficient to deal with the terrestrial system as it exists in Wytham Woods. Within the formation are "vertical layers": these are, in fact, horizontal zones some inches or feet deep, arranged vertically one above the other. All these four formation-types begin at base with the relatively undisturbed "sub-soil" which, if it is not rock, can be identified by its being penetrated by tree roots and the burrows of badger and fox. The sub-soil is followed by the "top-soil" and then the "ground zone"; the demarcation between these two is that the roots of plants occur below the dividing line and green stems and leaves above it. The ground zone may be quite thin but can normally be expected to be about six inches deep when there is vegetation, constituting any of the usual formation-types, above it. Objects, such as logs, lying on the ground are considered as part of the ground zone even when they project well above the general upper level of the zone.

In the open ground formation there is only "air above" over the ground zone. Air above is the air into which flying or leaping animals from the layer below will pass as they move from one part of the vegetation to another. In the field type formation there is a "field layer" of up to six feet in depth; in scrub formation a further layer called the "low canopy"; and in woodland formation an additional layer called "high canopy" before the air above is reached. Higher than the air above is the "high air system" with its aerial plankton and predators like the swift.

Between the formation types there are "edges" which are zones of transition. Qualifiers are also applied to the formations. Thus "acid", "non-acid", "maritime" and "arable" are qualifiers which can be applied to open ground and field type formations. On this basis seilles). This considered the use of thermionic solar energy convertors. Solar energy was not used merely to heat the electron emitter, but also used for neutralizing the space charge by the ionization of caesium vapour in the space between the electrodes. A. VECHT

# BRITTLE FRACTURE

THE brittle fracture of ceramics, glasses, metals and amorphous glassy polymers (plastics) was the subject of a meeting held at the Rubber and Plastics Research Association, Shawbury, Shrewsbury, Shropshire, on December 6, 1965. The title was chosen to indicate a concern for the behaviour of real materials rather than the classical theoretical models. The discussion was divided into four parts, each devoted to one material, and the significant features of the fracture behaviour of each of them were reviewed by four main speakers—Dr. F. J. P. Clarke, A.E.R.E., Harwell (Ceramics); Dr. D. M. Marsh, Tube Investments Research Laboratories, Saffron Walden (Glasses); Prof. K. E. Puttick, Battersea College of Technology (Metals); and Dr. J. P. Berry, Rubber and Plastics Research Association, Shawbury (Plastics).

It was clearly desirable to define or at least to clarify the basic concepts of the subject, but there were marked differences of point of view and opinion. No universally acceptable definition of "brittle fracture" could be formulated and it was clear that the more complex the mechanical response of a material, the more difficult it is to describe precisely its failure characteristics. For metals, which caused the greatest controversy at the meeting, it was concluded that instead of seeking a precise definition, behaviour should be described in terms of specific characteristics such as the micromode of failure, crack stability, local deformation and the like.

The theoretical foundation for much of the discussion was the energy balance approach of Griffith, but here too there was some difference in the interpretation of the theory, particularly between the physical scientists and the engineers. The former were concerned with the relation of the theory to the detailed mechanism of failure, and the latter with its relation to the stability of engineering structures. This led to the question, not completely resolved, of whether the condition given by the theory is both necessary and sufficient for fracture.

The aspects of fracture common to all the materials are (i) initiation and the nature of the primary flaw, (ii) the fracture surface energy, and (iii) crack propagation.

*Initiation and the primary flaw.* Contrary to the simple Griffith model, the flaw which is responsible for failure in ceramics, plastics and metals is not present as such in the unstressed material. In ceramics the mismatch in expansion coefficient at grain boundaries produces local concentrations of stress which can result in the formation of micro-cracks at applied loads less than those required for fracture. Similarly, in glassy plastics the crazes produced at relatively low stresses result in failure at the ultimate stress and, in metals, flaws are produced by slip or twinning processes. The details of the flaw generation process are different in the three cases, however. Ceramics have little capacity for plastic flow and little energy is dissipated in forming the flaws. In plastics the craze structure is complex; it represents a region of local yielding under hydrostatic tension and the structural changes that occur result in void formation and molecular orientation. Plastic flow is intimately concerned in the formation of the primary flaw in metals.

In glasses the flaws probably arise adventitiously, by mechanical damage, and correspond more closely to the primary flaw as defined in the Griffith theory.

*Fracture surface energy.* The application of the Griffith criterion to the fracture of a material yields a value for the energy required for the formation of unit area of fracture surface. For all the materials the energy, determined experimentally, is much greater than the true surface free energy, and the discrepancy can be accounted for by (*a*) the non-planar character of the fracture surface, (*b*) the formation of subsurface flaws, and (*c*) inelastic processes occurring at the fracture plane. All three factors have been considered in explaining the behaviour of ceramics but it is not yet possible to assess their relative contributions. In plastics the discrepancy is believed to be due to structural changes at the fracture surface which can be detected optically. Similarly the discrepancy in metals is attributed to the plastics flow processes occurring at the fracture plane. Only recently has it been shown conclusively that the fracture surface energy of glass is much greater than the theoretical value. Indentation experiments indicate that glass can deform inelastically and the discrepancy of surface energy may be due to this. Indirect evidence indicates that the zone in which the energy is dissipated extends only 60 Å from the fracture plane.

*Crack propagation.* The Griffith theory implies that the application of a certain critical stress will cause crack extension and fracture. The behaviour of real materials is much more complex. In ceramics, the surface irregularity and hence the fracture surface energy increases with the length of the crack and it is not obvious which combination of the two factors corresponds to the onset of catastrophic crack propagation. The initial rate of growth of a crack in plastics is low, but after travelling a short distance it suddenly and discontinuously increases. The reason for this is not known, but it may again be the result of the dependence of fracture surface energy on crack length. The similar change in crack velocity observed in metals is considered to involve a ductile brittle transition at a particular size of yielded region, possibly because of increasing triaxiality of the stress at the crack tip. The plastic zone at the tip of a crack travelling in glass is much smaller, and no change in velocity or surface configuration corresponding to a transition from brittle to ductile has been detected. Its influence, however, is felt in reducing the terminal velocity below its theoretical value.

At the meeting there were many points of similarity and difference in the behaviour of the materials under review and they were of particular interest when they were unexpected, as were some similarities of the behaviour of materials of different structure, and some differences of behaviour of similar materials. Observations on one material frequently suggested that interesting results may be obtained from similar experiments on other materials or by searching for effects and correlations which have not previously been considered. In this respect the meeting fulfilled its objective, and, it is hoped, supplied the stimulus for further studies to provide a better understanding of the complex phenomenon of brittle fracture. J. P. BERRY

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national scientific co-operation provides a basis for developing effective contacts between nations with widely different political systems. In such programmes, all ultimately depends on the willingness of individual nations and the energy and enthusiasm of their individual scientists. In the Antarctic, now as in the earlier "heroic age" of exploration, all achievement likewise depends on the energy, enthusiasm, and willingness to co-operate of each individual member of the national and international team. Judged against the direct record of research achievement and the indirect by-products of international amity and understanding, Antarctic science over the past decade has been an outstandingly good investment.