ZOOLOGICAL RESEARCH AND ANIMAL LEARNING

ON the first day of the recent meeting of the British Association at Sheffield, the presidential address by Dr. W. H. Thorpe to Section D (Zoology) (see *Nature*, September 1, p. 473) was followed by a series of papers on "The Contribution of Zoological Research to Theories of Animal Learning".

Dr. Peggy E. Ellis (Hope Department of Entomology, Oxford) opened with an account of some experimental work on gregariousness in the desert locust (*Schistocerca gregaria*). Locusts reared in the laboratory in company with other individuals started to form groups some hours after hatching. When ten such individuals were tested under standard conditions in a ring-like cage, 70–80 per cent formed groups by the end of the first day, and the proportion remained more or less constant on the following days. Locusts reared in isolation and afterwards placed in crowded conditions, however, at first tried to escape from aggregations, and became gregarious only after several hours. When such individuals were tested in the ring-like cage, at first only 45–55 per cent formed groups, though the proportion rose to 70–80 per cent during the first day. Once the locusts had learned to aggregate, the behaviour seemed to be fixed. Thus insects kept under crowded conditions for three days, and then isolated for several days, did not lose their gregarious tendency.

From such experiments it seems that positive gregariousness depends on a learning process which resembles 'imprinting' in being rapid, irreversible and in involving a learning of 'supra-individual' characters. It differs from imprinting in that there is no sensitive period—individuals reared in isolation can learn to become gregarious at any age. Dr. Ellis related her experiments to the behaviour of hoppers in the field and her lecture was illustrated by a colour film taken in Ethiopia.

Dr. S. A. Barnett (Department of Zoology, Glasgow) then presented a paper on "Animal Motility and Learning". Early scientific work on animal movement was concerned primarily with the control of orientation and directed movement, the approach being narrowly mechanistic. Later, the importance and role of appetitive behaviour were appreciated, and investigators were concerned with the initiation as well as the orientation of the movement. Dr. Barnett used the term 'appetitive behaviour' only for behaviour which is (a) specifically motivated and (b) related to a consummatory act, and pointed out that some variable movement is not appetitive in this sense. Thus 'exploratory behaviour' is widespread among animals but does not lead to any specific act. Appetitive and exploratory behaviour are important in that they provide opportunity for learning—exploratory behaviour, in particular, makes possible topographical learning. Such learning is independent of the satisfaction of a particular need—a fact surprising to the learning theorist accustomed to manipulate motivation in experiments on learning, but not to the zoologist, who thinks in terms of survival value. In its independence of specific needs and acts, exploratory behaviour resembles play; such behaviour is of course of particular importance in the primates and in man.

The first paper in the afternoon, by Dr. R. A. Hinde (Ornithological Field Station, Department of Zoology, Cambridge) was concerned with "The

Significance of Imprinting"—'imprinting' being used in its original sense to refer to the learning of the characteristics of their parents by young birds, and especially to the learning occurring when young nidifugous birds follow their parents. Among the characteristics of imprinting and the following-response discussed were:

(a) The diversity of objects which can elicit following. This can be understood functionally: responsiveness limited to one or a few stimulus patterns would be too selective, for the juveniles have not yet acquired a sense of constancy of size and shape and might fail to follow the parent when the latter was seen in varying postures and from varying angles.

(b) The ambivalence of the young, which tend to flee from their parents as well as to follow. This is a consequence of the selective advantage to adults of caring only for their own offspring and of driving off others.

(c) Irreversibility, rapidity and 'the sensitive period'. By virtue of such characteristics Lorenz believed imprinting to be a special form of learning. These characteristics are, however, by no means peculiar to imprinting, and can be found to a comparable degree in other contexts. Furthermore, all are covered by William James's laws of instincts.

(d) Imprinting and the parent-offspring relation. For a full understanding, imprinting must be considered in relation to all the behaviour patterns operating between parent and young: it plays an essential part in building up the parent-offspring relationship.

Since the characteristics of imprinting in birds can be understood functionally, learning with similar characteristics can be expected in other contexts with similar functional requirements. Thus the relationship between human mother and baby is built up in a similar way and shows many characteristics in common with the analogous relationship in birds, though the underlying mechanisms are presumably different.

A paper by Dr. I. M. L. Hunter (Department of Psychology, Edinburgh) entitled "Trial and error versus Insight" followed. Much of the problem-solving behaviour of animals seems to be 'almost human', and it seems reasonable to suppose that the animal 'understands' the situation. Such a supposition may, however, be wrong, for the animal has had a long learning history during which complex performances may have been developed by a process of trial-and-error learning which in no sense indicates the presence of thinking. In other cases the apparently intelligent behaviour of an animal may even turn out to be devoid of any learning at all: thus some of the strikingly purposeful behaviour of insects has been found to be instinctive, depending on a complex behaviour pattern which is, as it were, built into the organism.

The question whether animals think is thus more difficult to answer than it might appear. We need to know whether animals, whose past history is known in detail, can reorganize their past and present experiences to produce an anticipation of truly novel relationships within the problem situation. Only if this is so is it justifiable to speak of 'thinking' in animals. However, within the past ten years this

has been actually demonstrated. In chimpanzees, kept under continuous observation from birth, familiar material may suddenly and adroitly be used in a genuinely novel way as, for example, when a T-shaped stick is used to rake in food which lies out of manual reach beyond the bars of the cage. In white rats, certain types of maze experiment—the so-called reasoning and latent-learning experiments—have shown that these animals can make inferences about the spatial characteristics of certain situations, since they can run deftly from one place to another by paths which they have never before traversed. These and other findings lead to the conclusion that thinking exists not only in humans but also in animals, at least within the mammalian range.

Dr. Hunter suggested that the importance of such experiments not only demonstrates the existence of animal thinking but also contributes to the understanding of human thought processes. They have shown, for example, that thinking occurs only when the animal has had certain appropriate experiences in the past, experiences which contribute to thinking by furnishing, as it were, the raw material out of which a new response pattern can be formed. The experiences of early life seem to be especially important in this respect. Because it is easier to control the exact conditions under which animals can be reared (whether, for example, their visual environment is rich or lacking in detail), experiments with animals are particularly suited to yield information on the effect which early perceptual learning has on the emergence of thinking. In this way, animal experiments will supplement the considerable body of work which is currently being done on the nature and development of human thinking, and will provide answers to questions which could not be feasibly tackled at the human level.

Dr. A. J. Watson (Department of Experimental Psychology, Cambridge) discussed "Stimulus-response Theories of Animal Behaviour in the Light of Work on Instinctive Behaviour". He directed attention to three ways in which work on instinctive behaviour could lead to modification in theories of learning as devised by psychologists.

(a) Theories of learning are really theories of 'behaviour'—they attempt to predict what an animal will do in a certain range of circumstances. Furthermore, current learning theories are all in a sense stimulus-response theories; that is, given one set of stimulus conditions, and another of response conditions, an attempt is made to unite the two so that the second can be inferred from the first, but nothing is postulated about the actual mechanisms which intervene. Just because the initiating conditions, the final state and the intervening mechanisms are so complex, such attempts at prediction are almost bound to fail. Another type of approach is therefore necessary.

This is provided by instinct theories (for example, McDougall, Tinbergen) which permit distinctions between different 'kinds of responses' in different situations; for example, between appetitive and consummatory behaviour. Such distinctions cannot be accommodated within, for example, the Hullian framework, and permit an analysis of the problem so that it can be studied piecemeal.

(b) Instinct theories have emphasized the goal-seeking and directive properties of behaviour, which enter rather as an afterthought into theories of learning. This is related to the concepts of motivation used; in ethological theories the 'drive' selects the

stimuli for which the animal searches in its appetitive behaviour, while in learning theory the drive serves only to provide a perpetual internal stimulus which may become linked to responses in the same way as an external cue. Further, the retroactive effect of drive reduction in learning theory is without parallel in instinct theories. The instinct-type theory, involving a 'goal-seeking' system, is superior to a stimulus-response system both because of its simplicity and because it can deal more readily with variable behaviour leading to a constant end. The retroactive effect of drive reduction is an unnecessary postulate, for goal-seeking machines can be made to learn what cues to search for without invoking any such principle.

(c) Dr. Watson suggested that instinct and learning theories differ in the nature of the goals which they postulate. While instinct theories have tended to emphasize the importance of acts as goals, psychologists have laid more stress on the perception of stimuli. The evidence is in favour of the latter view, and on this issue, therefore, ethologists seem to be farther from the truth than students of the theory of learning.

Thus ethological studies suggest that the student of the theory of learning should attempt to build a theory of a different logical type—with room for different 'kinds' of behaviour—and that he should modify his treatment of motivation. Ethologists, on the other hand, could usefully study the treatment of consummatory situations by learning theorists.

Finally, Mr. R. L. Reid (Department of Psychology, Aberdeen) spoke on "Avoiding Theory", expressing the view that the study of behaviour might progress more rapidly with fewer theories. Among the types of theory which could, in his view, profitably be discarded are:

(a) Escapist theories which attempt to explain a phenomenon away. Thus when a worm learns to turn into that arm of a T-maze in which it is shocked, its behaviour can be explained away by saying that 'worms like electroshock', or by supposing the synapses to be directly affected by shock. The first is mentalistic, the latter a physiological fairy tale, and both are unverifiable: they merely translate statements about behaviour into a different language.

(b) Behavioural cosmologies. These are super-ordinate theories which usually reflect the theorist's values and metaphysical assumptions, but are irrelevant to the practical aim of predicting behaviour. Arguments about holism and analysis or the purposeful nature of behaviour may obscure agreement about facts.

(c) Formal theorizing. This results from the use of hypothetico-deductive schemes (for example, Hull) and theoretical models (for example, Estes, Bush and Mosteller). These are unlikely to be fruitful in the study of broad areas of behaviour because of the complexity of the problems involved. Although they may be suitable for exploiting limited areas where the facts are already known, the urgent need—while the gaps in our knowledge are still so great—is for factual survey work. Such formal approaches are inevitably constrictive: although there is room for formal theorizing, the less pretentious inductive approach must not be neglected.

(d) Physiologizing. In thinking about complex behaviour it is sometimes disadvantageous even to consider possible mechanisms. Thus the concepts of 'set' and 'attention' were disposed of in the early stages of behaviourism largely because they did not

fit in with the picture of the nervous system then held. They have now been restored on the grounds that they are physiologically respectable. Behaviour is as real and as regular as the physiological events underlying it, and reduction from the one realm of discourse to the other is unnecessary.

Mr. Reid concluded by hoping that zoological research will continue to provide empirical studies of learning in a wide variety of animals, and to examine

the effects of hitherto neglected variables, rather than indulge in speculative theorizing.

In his concluding remarks, Dr. Thorpe directed the attention of those present to the growth of liaison between psychologists and zoologists studying behaviour. Five years previously they would barely have understood each other's problems, whereas now each has a broad knowledge of the other's work and they are aiming at similar goals.

R. A. HINDE

THE PHYSICAL PROPERTIES OF METALS

ALTHOUGH the British Association has no section dealing specifically with metallurgy, it was to be expected that the recent meeting in Sheffield should give prominence to the subject. Thus the morning session of Section A (Physics) on September 3 was devoted to physical metallurgy, and Sir George Thomson, president of the Section, presided. The first paper, "The Physical Approach to Metallurgy", was presented by Prof. A. G. Quarrell (Sheffield) and served as an introductory lecture to the morning's proceedings. It emphasized the complexity of the technology of metals to-day and described how physics has provided not only the techniques for studying metals but also the necessary mental approach to the ultimate nature of metals which is leading to an understanding of their strength and behaviour.

Metallurgy as a science dates from the application of the microscope by Sorby to metal specimens at Sheffield in 1863, and a unique series of ferrous metallographic specimens laboriously prepared by Sorby in 1864 was on view at the meeting. Fortunately, these have been preserved by a cover-glass cemented on each prepared surface, and many may still be examined at high magnification. Sorby realized that the structure visible in polished and etched specimens is characteristic of the metal and the way it has been produced, and some time later it was shown that the appearance is also related to the mechanical properties of the metal.

The maximum magnification with the optical microscope is about $\times 2,000$, but about fifteen years ago the development of the electron microscope led to an increase in the useful magnification up to $\times 100,000$. Unfortunately, direct observation of the metal surface is normally impracticable, and a replica which is transparent to electrons must be examined. The initial unreliability of replica techniques prevented the general acceptance by metallurgists of electron microscopy, but the use of vacuum-deposited carbon replicas during the past two years has completely revolutionized the situation, and the electron microscope is now a most powerful metallurgical tool.

The early optical microscopic examination of metals was soon supplemented by thermal and dilatometric studies, enabling the composition limits of the various metallic phase fields to be determined and constitution diagrams to be constructed. The understanding of the alloy formation, however, had to wait for the technique of X-ray diffraction and for the concept of a metal as an assembly of charged ions surrounded a cloud of the conducting electrons. Hume-Rothery then showed in 1926 that the limiting solubility in monovalent metals such as copper and gold depends on the relative atomic diameters of the metals concerned, and that the structure of the

intermediate alloy phases depends on the ratio of valency electrons to atoms in the alloy. These rules unfortunately fail to explain the alloying behaviour of the more complex alloys which are important in modern technology, and the approach to these alloys is still largely empirical.

The appreciation of the crystalline structure of metals has also made possible the study of the factors influencing the strength of metals. However, the theoretical strength of metals calculated from their atomic properties is 100–1,000 times greater than the measured stress required to produce permanent plastic deformation. This weakness is due to imperfections in the lattice, known as dislocations, and since the 'edge' dislocation was introduced in 1934 a complex theory of dislocations and their behaviour in crystal lattices has been developed. It has been calculated that the stress necessary to move a dislocation, if the interactions between the dislocation and the stress fields due to alloying atoms and precipitates are taken into account, is similar to the stress required to initiate slip in practice.

The dislocation theory of plasticity has been developed by theoretical physicists such as Mott and physical metallurgists such as Cottrell, and while strain-hardening, yield-points and crystal growth have been explained satisfactorily, only a beginning has been made towards the understanding of creep, fatigue and brittle fracture.

Creep is an example of a phenomenon of interest to both physicist and metallurgist; it was studied by Andrade in 1910 as a purely scientific phenomenon, but in 1920 Dickinson, in Sheffield, appreciated the importance of creep in steels at high temperatures and carried out the first long-time creep tests. These showed that at high temperatures much lower stresses would cause stretching and failure in the long-time creep test than in the short-time tensile test. The importance of creep in modern engineering has grown enormously in recent years with the trends towards high operating temperatures and pressures, and a large proportion of our metallurgical man-power is concerned with the development of new creep-resistant alloys which, for example, would be expected to last for many years at 570° C. in a modern power station.

Although complex metallurgical problems such as the mechanism of creep and its relationship to structure have not been solved completely by the physical approach, and resort must be made to semi-empirical methods, the major contribution of physics to metallurgy has been to give metallurgists a new mental attitude. Metallurgists are no longer satisfied with *ad hoc* solutions of immediate problems and have become increasingly anxious to provide fundamental explanations of important phenomena.