production. The deep crustal level represented by many Archaean rocks now exposed at the surface conveniently gives us insight into the chemical and petrogenetic processes occurring in the deeper reaches of the continental crust, not normally observable at those accreting or colliding plate margins where young continental crust is nowadays being created or reworked.

Certain aspects of the subject are efficiently dealt with in this useful volume, whose stated aim is to summarize some of the main issues in the broad geochemistry of Archaean rocks which were addressed during a nine-year stint of one of the projects ("Archaean Geochemistry") of the International Geological Correlation Programme. Topics range from the accretion history of the Earth and composition of the primordial mantle to greenstone belt evolution, petrogenesis of komatiites, the nature of high-grade gneiss terrains and the role of fluids in their development and geochronology, and the relation of Archaean sediments to the overall composition of the Archaean continental crust. Also included are geochemical and geochronological data on regions in the Soviet Union, China and India which were hitherto little known in the Western literature. It is refreshing, for once, to see some reliably documented new isotopic age data from the oldest shield areas of the Soviet Union to which up-to-date analytical and interpretative techniques have been applied.

I regret the absence of a contribution on the rapidly developing field of biogeochemistry and related topics, since the Archaean saw the transformation of "primordial soup" into the highly organized, far-reaching second course. Some discussion of Archaean metallogenesis would also have interested geochemists. □

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Red Tam nestling in the Helvellyn corrie. From Discovering Landscapes in England and Wales *by Andrew Goudie and Rita Gardner. Published by George Allen & Unwin at £12.95.*

Animal cognition

Geoffrey Hall

Animal Intelligence. Edited by L. Weiskrantz. *Clarendon:1985. Pp.223. £32.50.*

THE publication of this work (the proceedings of a Royal Society discussion meeting) just over a century after the appearance of *Animal Intelligence* by G. J. Romanes tempts one to make comparisons. Romanes was interested in animal intelligence because he felt the findings of comparative psychology had as much relevance to Darwinian theory as did those of comparative anatomy.

Romanes would be at home with Jerison's contribution to the present volume, a chapter which charts the evolution of encephalization and the implications of brain size for mental activity. But, as Jerison points out, little use is made elsewhere of evolutionary theory in organizing the wide range of facts about animal behaviour presented by the various contributors. One of the reasons for this neglect may be discerned in the chapters by Macphail and by Mackintosh and his collaborators. Although Romanes felt able to rank the various animal groups according to their level of intelligence (his scheme is reproduced in Weiskrantz's introductory chapter), modern experimental studies of animal learning (such as are reported by Mackintosh) have found precious few differences between species that can be unambiguously interpreted as being the result of differences in intelligence. Macphail concludes that we might as well accept what he calls the "null hypothesis" — that extant non-human vertebrates do not in fact differ in intelligence.

Romanes has been castigated by subsequent comparative psychologists for basing his conclusions on mere anecdote rather than on careful observation and experiment. To some, Macphail's conclusion may seem not so much an accurate judgement of the intelligence of animals as a condemnation of the skills of modern experimenters. And certainly, some of the most striking examples of intellectual achievement among animals reported in this book come not from laboratory studies but from observations made in natural or semi-natural conditions. Goodall concludes her intriguing survey of the innovative behaviour displayed by the chimpanzees of Gombe with an assertion of the value of (carefully documented) "anecdotal" reports of natural behaviour.

However this may be, none would deny the need for experimental analysis in any attempt to determine the mechanisms responsible for seemingly intelligent behaviour and much of this book is devoted to reports of such work. Several chapters present accounts of the behaviour shown by primates when solving the problems set for them by experimental psychologists. It is made clear that their behaviour cannot be interpreted simply as the acquisition of new habits and must require intelligence of a higher order. But perhaps this has never really been in doubt. More significant, therefore, is the elegant analysis presented by Dickinson of the mechanisms by which that least esteemed of animals, the laboratory rat, learns the simplest of tasks, that of pressing a lever to obtain food. What emerges is a need to allow the rat knowledge about the relationship between its actions and its desired goals, and credit it with the ability to carry out inferences on the basis of that knowledge. No more than this is claimed for the primates, a fact that not only speaks in favour of Macphail's "null hypothesis" but also helps to justify the belief that has sustained so many studies of animal learning — that the study of cognitive processes in one vertebrate species will reveal principles of intellectual functioning that have general applicability.

It would be a disappointment if such general principles as emerge were to be found not to apply to our own species. But the possibility remains that human intelligence is different in kind from that shown by non-human animals, being based on our possession of a form of language that is beyond the capacity of any beast. Empirical investigation of this hoary notion long seemed impossible. But perhaps the most interesting implication of the recent attempts by several experimenters (Terrace, Gardner and Gardner, Savage-Rumbaugh and others are represented in this book) to teach a form of human language to an ape is that their work appeared to allow just such a possibility. Unfortunately, the outcome has been inconclusive. There is no real consensus as to what the apes have actually achieved or, more worrying, as to what it is that they would have to do in order for us to be sure that they had learned a language. An empirical solution seems as far away as ever.

More generally, this book leaves one with the impression of a field of study that is productively active, has achieved much in the hundred years since Romanes and is likely to achieve more in the near future. And this is only half the story. Romanes devoted roughly half of his book to the intellectual achievements of invertebrates. That these animals receive no mention in the present volume is its only serious failing. It is now becoming clear that the application of methods of study and analysis previously applied only to vertebrates can reveal evidence of equivalent intellectual sophistication in invertebrates. Our rapidly advancing knowledge of invertebrate neurophysiology fosters the hope that a comprehensive account of the biology of intelligence is almost within reach. □

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