Animal intelligence

SIR—According to Geoffrey Hall's review of *Animal Intelligence* (*Nature* 25 July, p.306) "... modern experimental studies of animal learning... 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... that extant non-human vertebrates do not in fact differ in intelligence". I would like to support the reviewer's comment that this conclusion is a condemnation of the skills of modern experimenters rather than an accurate judgement of the intelligence of animals. There is surely something very wrong with studies that show no unambiguous differences in intelligence between a frog or a chameleon — or even a sheep — and a sheepdog or a chimpanzee.

Very complex behaviour patterns can be built into the simple nervous system of an insect; a honey-bee can quickly learn to find its nest by what must be a quite comprehensive imprinting essential to the success of its way of life. The ability of a rat to learn its way through a maze may not have much relevance to its intelligence. Young rats may be programmed to learn complex and growing mazes of tunnels.

The primary function of intelligence must have been to improve the chance of survival or it would never have evolved. For a specific way of life in an unchanging environment, a built-in behaviour pattern that has been optimized by natural selection over 5 million years — a typical species lifetime — is not easily improved by an individual creature. Improvement must require occasional replacement of part of the built-in behaviour pattern by an anomalous behaviour locally more successful than the five-million-year optimum. This in turn requires three things. The first is a good memory of events in the individual's life, such as stumbling on a novel source of food in an accidental excursion into a normally avoided environment, or of a narrow escape by novel means from a novel hazard. The second is the ability to recognize the value of repeating the experience. The third is the ability to override the built-in behaviour pattern in order to do so.

The enormous gap between human and even the greatest animal intelligence could mean that we ought to use different words for them, but I believe that the difference is quantitative rather than qualitative. We passed a vital threshold when we became bright enough to carry throwable chipped stone weapons. A group so armed would have become very unattractive to the big predators, and survival from then on must have depended on intra-specific competition for food-bearing territory between groups. This did nothing to make us tolerant of groups of strangers but a lot to increase our intelligence. A second

threshold was passed when we developed language. The value of this in original practical thinking is often exaggerated, but its value in transmission of thought and knowledge and hence in inter-group fighting was overwhelming.

The value of intelligence will be much increased if the environment undergoes a large and permanent change. At the end of the Cretaceous period, the Earth seems to have been struck by a large meteorite and the resulting dust clouds may have persisted long enough to eliminate many species of plants and animals over large areas. The survivors will then have been thrown suddenly into a changed biological environment in which many of the less adaptable species may later have died out. Then those species, for example the early mammals, that could diverge from their built-in behaviour, and learn from their own experience and from novel behaviour of parents or other conspecifics, would have had a great and sometimes overwhelming advantage over those with rigid behaviour patterns.

To measure intelligence we must do

more than measure memory. The ability of a rat to learn a maze is a good test of memory, but could be using the same kind of built-in learning pattern as that of the honey-bee. It would be better to give the rat a chance of some lateral thinking by, for example, painting a particular scent on the wall in the middle of each straight section on the side to which the rat should turn at the next fork. Increased speed of learning another maze with the same cues could hardly result from any built-in pattern. Similar problems could presumably be arranged for a goldfish, a tortoise, or more expensively a chimpanzee.

To summarize, I believe that there are differences in intelligence, which must in principle be observable, between different vertebrates, and that there are understandable reasons why these should have arisen. Furthermore, in testing for intelligence, I believe that one should try to distinguish between memory and the ability to notice correlations between experiences, and should look for ability to override normal or usual types of behaviour.

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PhD theses

SIR—A PhD is supposed to be a training in research. Normally this process is conducted over a period of three years, financed by either government or industry, and involves three years' supervision by a university teacher, to which must be added the cost of equipment both capital and consumable, and technical assistance over the requisite period. The return for the many thousands of pounds of outlay per candidate is a thesis on a university library shelf and a piece of paper for the successful candidate which hopefully will enable him or her to command a higher salary than he or she could otherwise have expected.

While it is true that theoretically theses can be consulted in university libraries, in practice this is rarely done. References to PhD theses occasionally appear in the scientific literature, but usually only when an author refers to his own unpublished thesis.

Research is not recognized as having been brought to a conclusion until it has appeared in print in a recognized scientific journal. An essential part of training in research should be the preparation of the work for publication as a scientific paper. A PhD should not be awarded until there is evidence that the major new contributions to science have been published or at least accepted for publication in an appropriate reputable journal. If the material is not suitable for publication then it was not necessary for it to be done in the first place. If there are a large amount of basic data for which there should be ready access, then this could be

deposited in suitable archives as is already the practice with learned societies.

It must surely be time for the antiquated PhD thesis system to be thoroughly overhauled. The stupendous waste of resources cannot be justified at this time. It cannot be beyond the wit of man to devise a system more in keeping with present needs.

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Modest disclaimer

SIR—John Maddox's readable account (*Nature* 11 July, p.101) of the experiment that T. Corle and I made to measure Maxwell's displacement current inside a capacitor as it is being charged does us too much credit. Although we may have been the first to measure the profile of the magnetic field between the capacitor plates, we were not the first to measure the total magnetic flux.

That experiment was done almost 60 years ago by M. R. van Cauwenberghe (*J. Phys. Radium* 10, 303; 1929). The title of that work, "Vérification Expérimentale de L'Équivalence Électromagnétique entre les Courants de Déplacement de Maxwell et les Courants de Conduction", aptly expresses the results of a very pretty measurement which used an iron-core, toroidally-wound solenoid to measure the magnetic flux through the central portion of a capacitor.

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