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Book Review

The Memory System of the Brain, by J. Z. Young, 1967, 128 pages. (London: *Oxford University Press*, 28s.)

In any computer, whether in flesh or metal, there must be two main classes of mechanism, clocks and stores. This book is a collection of lectures delivered by Professor Young in California in 1964 about some properties of the latter, the storage mechanisms, but "the Brain" is not of man but of Octopus. As in other works in this domain the definite article is still misleading, and authors may envy their Russian colleagues whose language enforces ambiguity of reference.

Lacking a systematic functional taxonomy, neurophysiologists must be content with whatever information they can glean from any creature whose behaviour can be observed without too much disturbance or expense. Young and his colleagues have exploited the cephalopod with incomparable ingenuity and patience for many years and have been able to identify specific structure-function relationships more confidently than would be possible in a more advanced animal.

The natural history of Octopus is particularly fascinating and this is surveyed in more detail in Young's longer work, *A Model of the Brain*, but in these lectures too there is enough detail for the reader to be able to identify not only with the author but with the subject-animal. As Young admits, the first step in cryptography is often to guess what the messages are likely to be about, and here this means looking at the submarine world with the large and liquid eye of an Octopus. One has eight sensitive and powerful tentacles, excellent eyesight (with colour-vision) and a voracious appetite particularly for small crabs. One lives in a stone-built cottage in a charming seascape but difficult of access. One can crawl or boost one's power by jet-propulsion. When in trouble one can withdraw to one's home behind a smoke screen. The sea being, as we all know, cruel, one must approach a doubtful quarry cautiously, ready to retreat at once if it bites, but prepared to attack more quickly if it is harmless and edible. One can learn from such experiences in a few trials, remember the lesson for several weeks and change one's mind if first impressions turn out wrong. One has two memory stores in distinct locations each with specialized storage elements. One is thus almost ideally fitted to be the prey of the universal predator—the human scientist. The only slight protection against extensive interference is that, living in salt water, one is unlikely to have electrodes implanted in one's brain as happens to most terrestrial animals. Surgical mutilation, however, cannot be avoided, and it is mainly by this means that one contributes to human knowledge.

What hypotheses have been constructed from observations on this obliging beast? The basic proposition is "that learning consists in the limitation of choice between alternatives". The establishment of the models of the alternatives in the memory of an animal is "like the printing of a book in that it involves selecting appropriate items from a pre-established alphabet". But since each species of animal has a limited repertoire of responses, its stock of symbols must also be limited. "Brains are not general-purpose computers but specialized analogues." Whether this last assertion is universally true and useful is still a matter for discussion and experiment. The human brain seems to have such a vast capacity and to be so nearly independent of hereditary constraints that any statement about the class of computer to which it belongs would have to be qualified by definition of the conditions in which it is to be used or studied.

No analogy or metaphor can conceal the overwhelming magnitude of the human brain. That there are 10,000,000,000 neurons is bad, but not incommensurable with the imaginable scale of the artificial molecular circuitry of the future. If these were living flip-chips we could hope to penetrate their logic. But on some of these cells there are at least 10,000 contacts and in some of these contacts there may be thousands of sub-microscopic chemical vesicles.

It is because of this intractable complexity that Octopus brain is so reassuring—combined of course with the supposition, based more on hope than conviction, that there may be principles common to cephalopod, computer and ourselves. Assuming that learning in all cases involves a modification of memory resulting from a choice between two specific alternatives—a binary decision, how is this choice or decision implemented? In the simplest models one can start either with a system in which all channels start open and those unused or ineffective are progressively blocked, or with one in which no throughput is possible until associations have been classified and accepted, when the appropriate channels are opened for these specific contingencies. It is the first system that is suggested by Young's studies of Octopus, that is, learning by blocking un-needed channels. From the biologic standpoint this hypothesis has the advantage that the raw material for conditional inhibition is present at an elementary level of evolution in the negative feedback pathways that are so prominent in primitive reflex action. The complementary positive feedback circuits exist, but they would leave the alternative channels open, which would seem extravagant.

(*Continued on p. 189*)

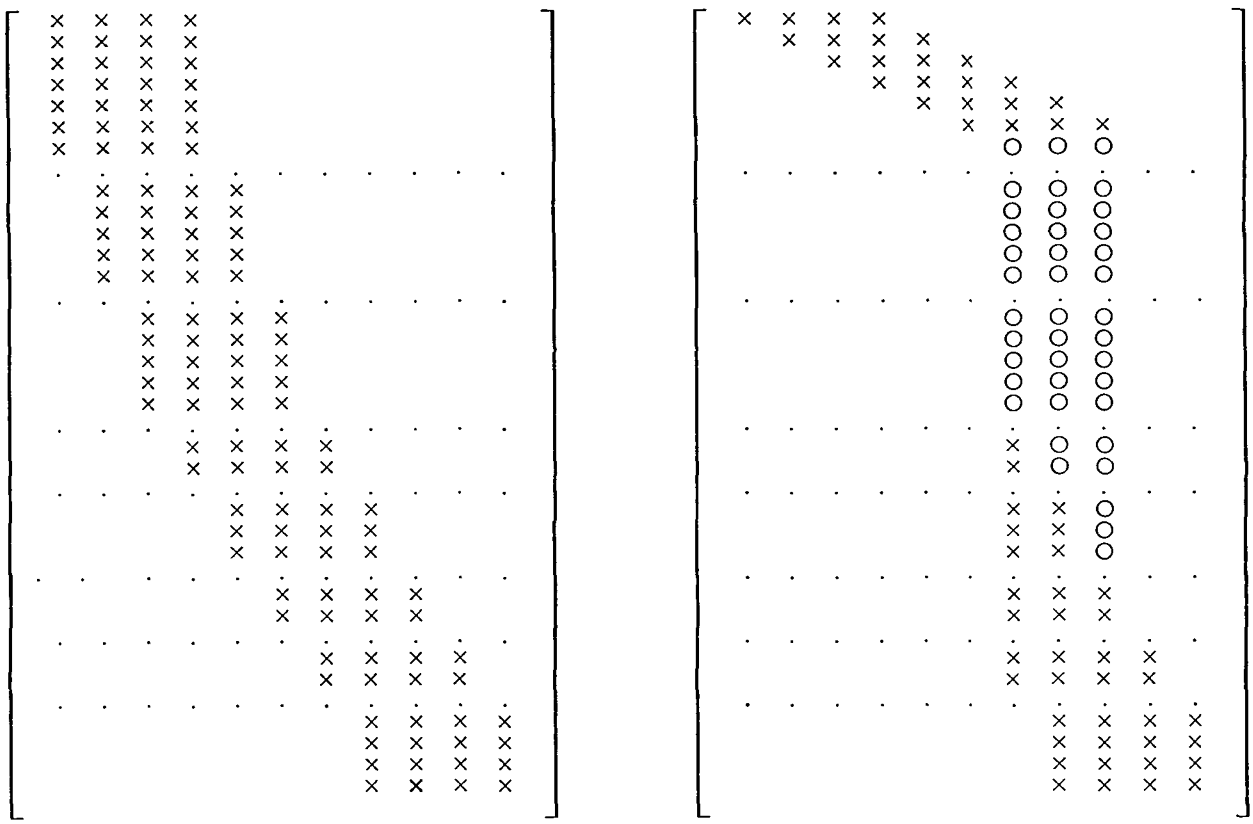

Fig. 1. The form of a band matrix before reduction is commenced and at a typical intermediate stage

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Book Review (*Continued from p. 187*)

In more complex systems, where the selective information is greater than for the binary choice "fight or flee" this dichotomy may not be so easy to define. When the other essential computer component, the clock, becomes really important there is no longer a sharp distinction between excitation and inhibition. As far as Young reports Octopus is not a good judge of elapsed time, while vertebrates and particularly man are notable for their accuracy even without adventitious aids, and even in states of diminished awareness or distraction. Some of the electrochemical processes in higher brains look very like the unwinding and striking of an alarm clock, and an alarm clock is both excitatory—it wakes you up—and inhibitory—it avoids your awakening too soon.

The final conjecture in this admirable collection may apply not merely to us who regret that the arrow of time points to the grave, but also to those who are more prosaically concerned with the breeding and grooming of more sophisticated computers—the greater our capacity for learning the longer we must live in order to learn. In a sense men never grow up; if our great brains are not to destroy our species "We must become even more like little children".

W. GREY WALTER