DESIGN FOR A BRAIN

THE problem of how the brain functions in living organisms to produce the kind of behaviour designated as 'intelligent', 'purposeful' or 'adaptive' is one to which much attention has not been directed so far. While it is not disputed that the brain, whether in man or the lower organisms, resembles a machine in many ways, many workers believe that a mechanical model, however intricate, can never explain satisfactorily the capacity of the brain 'to learn by experience'.

In this connection, the volume *Design for a Brain** by Dr. Ross Ashby will be read with wide interest ; for Dr Ashby proceeds to show how a mechanical model can, in fact, be constructed having the capacity to adapt itself to the environment. In other words, the model reacts to external stimuli in such a fashion that its behaviour improves with each new experience. Naturally, only simple examples can be given at present exhibiting this capacity ; even so, it is interesting to study in broad terms what the properties of such a system should be, subject to the known laws of mechanics, if it is to behave adaptively.

Dr. Ashby finds the solution in the existence of 'step functions' among the various parameters defining the behaviour of a system. While a large majority of the parameters are continuously variable, these step functions can take only specific values. For a particular value of a step function (S, say), the behaviour of the system with respect to the rest of the variables will appear to be independent of S, but if S changes by a discrete jump to a new value, the whole field of the other variables will be entirely altered. A physicist is strongly reminded in this connection of some of the concepts of quantum mechanics, such as eigen-values and stationary states.

Suppose it is arranged that S undergoes a transition only if the system is unstable with respect to the other variables, say, if one of the variables exceeds a given value. Then, for the new value of S, the system may be stable, the other parameters remaining unchanged. If not, S undergoes further transitions until a suitable value is attained for which the system is stable, and thereafter a small disturbance does not make it unstable and no further transitions take place. It is obvious that such a system is able to adapt itself without any further external influence, for the step function is automatically altered as a result of the first few encounters until the system reaches a stable condition. In other words, if the facility of altering step functions every time an instability is encountered is included in the design of the machine, it is able 'to learn by experience', and always attains a stable state, irrespective of what state is started from. Such a system is called an "ultra-stable system". Here again, Dr. Ashby makes a statement which is interesting : the speediest way of reaching the stable state is not through systematic changes in step functions, but through a *random* choice of the allowed values of the step function.

Dr. Ashby has in fact constructed an apparatus consisting of four magnets interacting with one another, which he calls a 'homeostat', illustrating many of the above principles. If arbitrarily disturbed, it always returns within three or four steps to a stable state, in which it continues to remain until it is disturbed again.

The essential difference between the principles of ordinary automatic control and the homeostat is best shown by the following example. The automatic pilot is a device which, amongst other actions, keeps the aeroplane horizontal. It is, therefore, connected to the ailerons in such a way that when the plane rolls to the right, it exercises a corrective action on them and rolls the plane to the left. The homeostat, if joined this way, may also do the same. Now connect the ailerons in the reverse way and compare the present behaviour of the two systems. Whereas the automatic pilot will tend to increase the roll after a small disturbance and persist in its action to the very end, the homeostat will do so only so long as the increasing deviations made the step functions start changing. Afterwards, it would take on suitable new values and start stabilising. It would then be ordinarily self-correcting with respect to disturbances.

Here are entirely new concepts, which have immense possibilities in physics and engineering, apart from their ability to explain the phenomenon of adaptation in living beings. As will be clear from the foregoing, the concepts are essentially mathematical, but Dr. Ashby has explained these in his book with remarkable clarity and elegance. In the first 200 pages, he has stated his thesis in plain words, aided by a number of diagrams and tables, and then reformulated them in precise mathematical form in an Appendix of 60 pages. However, the first part never lacks in precision or rigour, which

* *Design for a Brain*, by W. Ross Ashby. (Chapman and Hall), 1952. Pp. ix + 260. Price 36 s/4.

forcibly brings out the fact that mathematics is only a tool for simplifying the manipulation of ideas and that it leads to no new result unattainable by logical thinking.

Dr. Ashby has succeeded in showing that mechanical systems may be made to modify their behaviour according to the conditions met with. But in extending this idea to living beings, a few points need to be carefully considered. While it is true that an ultra-stable system is "goal-seeking", the goal has to be known even before the system is built up. For a mechanical system, it may be defined as that state in which the system is "stable". However, with living beings, the goal itself may vary according to circumstances. In such a case, it is quite possible that other types of special properties will have to be invoked for various parts of the system.

For instance, no method has been suggested in the book whereby an ultra-stable system can "learn" by experience, that is to say, how the adaptation to a particular environment from a general state can be made more rapid during a second or succeeding encounters. Obviously, a mechanism must be devised whereby the random choice of step function values is changed to *deliberate* choice if the same environment is met with once again. These are rather recondite points, which need be considered only in future developments of the theory. There is no doubt that the present book by Dr. Ashby is an outstanding contribution to the mechanistic explanation of the behaviour of living beings.

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NRX, THE CANADIAN HEAVY-WATER PILE

THE NRX reactor at the Canadian Atomic Research Station at Chalk River has made possible a whole range of investigations in atomic energy and nuclear physics, not practicable elsewhere.

In reactors using natural uranium, the fast neutrons produced by the fission of the uranium 235 nucleus have to be slowed down to thermal energies to increase their chances of causing the fission of other uranium 235 nuclei, and the slowing-down process is achieved by the use of a 'moderating' material. In all existing reactors, the moderator is either graphite or heavy water. The American and British projects, with their emphasis on military uses, have concentrated on graphite-moderated reactors, which are most productive of plutonium. Canada, on the other hand, has been concerned with developing heavy-water reactors. The first, a low-power reactor known as ZEEP, gave the experience necessary for the construction of the second heavy water reactor, the NRX pile. The great advantage of using heavy water as the moderator instead of graphite is that it makes possible a smaller and more compact pile, and this means a pile with a higher neutron flux for a given power. The NRX pile, which was designed with power rating 10 megawatts, has a maximum neutron flux of 6×10^{13} neutrons/sq. cm./second, which is 10-20 times the flux in a graphite reactor of comparable size.

This very high neutron flux has made possible the commercial production of radio-active material in unrivalled concentrations, such as cobalt 60 which is produced by neutron irradiation of ordinary cobalt, and which is used as a substitute for radium in therapy and radiography because of its emission of penetrating gamma rays. It takes 18 months' irradiation in the high flux of the NRX pile to produce radio-cobalt samples with a specific activity of 35 curies per gm. Pieces of irradiated cobalt, which have an effective strength of 1,000 curies a piece, have been made for Canadian hospitals and used in cancer therapy.

VPI CRYSTALS FOR PREVENTING RUST

DICYCLOHEXYL ammonium nitrite, known commercially as the Vapour Phase Inhibitor, or VPI, is being used to-day to protect such a variety of products as small machine parts, aircraft engines, wire, hand tools—even tiny watch parts and huge diesel engine crankshafts. It not only affords greater protection than previous methods of rust prevention, such as coatings of grease, but it also reduces cost and is more convenient to use. When a small steel part, such as a gear, is wrapped in a sheet of VPI coated paper, coated side next to the gear, the VPI slowly vapourizes and diffuses all around the part. Oxygen that was present when the gear was wrapped is thus effectively neutralised.

Its rust-prevention qualities were first discovered by the Shell Oil Company, U.S.A.