THE LEARNING PROCESS IN A SNAIL.[1]

IN his well-known experiments (1904), the Russian physiologist Pavlov showed that salivary secretion in a dog, primarily induced by the odour or sight of food, could eventually be induced by a sound or colour which had been for a time synchronised with the primary stimulus. The dog, according to the experiments, was soon able to establish an organic association between the primary and the secondary stimulus. When Pavlov slightly changed the secondary stimulus there was a change in the dog's salivary reaction, and this was taken as evidence of the animal's power to discriminate between stimuli.

With noteworthy clear-headedness, Miss Elizabeth Lockwood Thompson has seen how to apply Pavlov's method to a water-snail, *Physa gyrina,* which glides about in ponds, with foot and mouth upwards, suspended from the surface-film. When a part of the body within a millimetre or two of the mouth is touched with a bit of food, a chewing motion of the mouth-parts is started. With the application of food to near the mouth there was synchronously associated a pressure with a clean glass rod at a fixed distance from the mouth. The next step in the ingenious experiment was to apply the associated or auxiliary stimulus alone in the absence of food, in order to determine from the presence or absence of reactions whether or not an association had been formed between the two sets of stimuli. Miss Thompson deserves to be congratulated, we think, on this extension of Pavlov's method, which he himself did not regard as applicable except to a limited number of mammals. It is now possible, along this line of investigation, to test a snail's power of "learning."

When food was applied to the mouth and at once withdrawn, response followed in 61 per cent. of the tests, the mouth being opened and closed on an average 3·93 times. By means of an apparatus a simultaneous application of pressure to the foot and food to the mouth was secured. In the first 60–110 trials of simultaneous stimuli no response followed; in the remaining trials, out of 250 in all, a response was always given. The snails were thus "trained." After forty-eight hours a response followed the pressure by itself, *i.e.* in the absence of any food-stimulus, but only for a limited period. Cessation of response to pressure after training is sudden and final. The limit of the effect of training (which simulates memory) is about ninety-six hours. An interesting waning of response (marked by a reduction in the number of mouth movements) was observed in some series of trials; it showed that the snails became adapted to a stimulus which was not followed by its wonted reward. The relation between length of training and training effect (as measured by response to pressure only) requires further investigation.

Miss Thompson also devoted many experiments to inquiring whether the snail could learn to solve a simple U-shaped or Y-shaped labyrinth with a picket fence of wires, one arm leading from near the foot of the tank to the air (the reward), the other not (the punishment). In some cases error was punished by an electric shock, and roughness of the path was used as a warning stimulus. The result was interesting. The snails showed no ability to learn that the one path was to be preferred to the other. But in 15 per cent. of a total of 930 trials in one series, the snails changed their course from the wrong to the right path after contact with a warning stimulus (in this case, slight irritation of the tentacles and the back of the head with a hair) before the shock (punishment) was received. There was formed a weak association between two stimuli, the hair and the shock, the former serving as a warning of the punishment to follow if the course be not changed. But the capacity to form associations, already proved by the method of using simultaneous stimuli, does not suffice for the solution of the simplest labyrinth. There was no evidence of "selective" ability.

Miss Thompson has made a very interesting contribution to the study of animal behaviour; the details of the experiments show the punctilious carefulness of her work.

[1] "An Analysis of the Learning Process in the Snail, *Physa gyrina*, Say." (Behaviour Monographs, vol. iii., No. 3, 1917, pp. 1–89+8 plates+12 tables.) (Cambridge, Mass.)

SCREW GAUGES.

THE production of a satisfactory screw gauge is a matter of considerable difficulty as regards both manufacture and testing, and the pamphlet on this subject just issued by the National Physical Laboratory[1] will be found to contain much useful information.

In the case of a plug screw gauge, it is essential that it should enter a standard check ring gauge, but this test is insufficient, since it may be complied with by a plug gauge having such a combination of errors as to enable it to enter the check and yet be useless for the purpose of gauging screws. "Not go" tests are also essential, and certain errors can be detected only by carrying out measurements on the gauge of either a mechanical or an optical character. The full (or major) diameter is measured by use of a micrometer in conjunction with a set of Hoffmann roller gauges. The core (or minor) diameter and the effective diameter are also measured by means of a micrometer, together with a pair of Vee-pieces and a pair of small cylinders respectively. The lathe in which the gauge is machined should be furnished with an attachment for holding the micrometer so that its axis intersects the axis of the gauge at right angles, and arranged so that the instrument can be readily removed. This permits of the gauge being measured as the work proceeds, without the necessity for removing it from the machine In instruments used for measuring these diameters in the inspection room, the micrometer should be held mechanically so as to comply with the same condition.

The machine described in the pamphlet for measuring the pitch of the screw appears to be both simple and effective. The actual measurement is made by means of a micrometer having a large dial reading to 0·0001 in. An ingenious arrangement, partly mechanical and partly optical, ensures that the axial movement of the micrometer point shall be exactly equal to the pitch of the screw under test. Both periodic and progressive errors in the pitch can be detected from the readings obtained in this machine.

As a general rule, optical measurements of screw gauges cannot be made to the same accuracy as mechanical measurements, but optical methods are of great service from the consideration that the whole of the screwed surface of a gauge can be examined in detail. Errors in angle, want of straightness of the threads, eccentricity between different diameters, and local bumps and hollows can be detected readily by optical means. Until recently, microscopes having cross wires in the eyepiece were alone employed for measurements, and a machine embodying this principle is made by the Cambridge Scientific Instrument Co., and is described in the pamphlet. Such methods have now been displaced to a great extent by a pro-

[1] "Notes on Screw Gauges." By the Staff of the Gauge-testing Department, National Physical Laboratory. Enlarged issue II. (Teddington: W. E. Parrott, The Causeway, 1917.) Price 2*s.* 6*d.*