

Gamble, and Mr. Hick from Owens College, Mr. W. I. Beaumont, and Mr. E. T. Browne. The steam trawler *Lady Loch* was chartered for two days, and the weather was perfect for work at sea. On the first day, the sea-bottom to the north of Port Erin, from Fleshwick to Contrary Head at Peel, was explored at twelve stations ranging from quarter of a mile to four miles from the coast, and from depths of ten to twenty fathoms. On the second day the steamer coasted along the west side of Calf Island and about four miles further to the west, dredging at nine stations from one to four miles from land, and at depths of nineteen to twenty-five fathoms. Two series of samples of the bottom deposits brought up in the dredge were preserved, the one set for more detailed examination in the laboratory, the other for transmission to the Jermyn Street Museum, where the Director-General of the Survey is forming a series illustrating the submarine deposits of our coasts. Besides the more ordinary gravels, sands, and muds, several peculiar deposits occurred, one of which was almost entirely composed of the shells of *Pectunculus glycymeris*, while another, which looked like a coarse sand, was seen to be formed of the broken spines of *Spatangus* and other Echinoderms. In some places the bottom for considerable distances is covered with *Melobesia* and *Lithothamnium*.

The greater part of the material obtained has still to be examined in detail, and will be treated of in future reports of the Liverpool Marine Biological Committee. Among the more noticeable forms obtained were:—The massive state of *Cilona celata*, *Sarcodictyon catenata*, the Echinoderms *Antedon rosaceus*, *Palmipes membranaceus*, *Luidea savignyi*, *Stichaster roseus*, *Echinocardium flavescens*, *Cucumaria hynchmani*, *Thyone fusus*, and *T. raphanus*, *Cellaria fistulosa*, *Scalpellum*, *Tellina crassa*, and the Ascidians *Polycarpa comata*, *Engyra glutinans*, *Ascidia plebeia*, *Cynthia morus*, and a *Microcosmus* which seems an unknown form. Mr. Thompson and Mr. Browne worked townets both on the surface and also at the bottom attached to the dredge. Most of the crabs and other higher Crustacea were found to be spawning, and some of the Nudibranchs are spawning in the tanks at the Biological Station. A common anemone a few weeks ago produced about fifty young, which have now from twelve to sixteen tentacles.

Several of the dredging party are staying on to work at the Biological Station during a part or the whole of April, and another dredging expedition will be arranged by the committee at Whitsuntide.

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University College, Liverpool, March 26.

THE SCOPE OF PSYCHO-PHYSIOLOGY.

UNDER the title of psycho-physiology may be comprised those investigations in psychology which have explicit or tacit reference to the concomitant physiological processes, and which are characterised by the application of the experimental method. The boundaries of the subject are somewhat ill-defined, since it shades off into physiology on the one hand, and into introspective psychology on the other. I shall endeavour in this article to indicate the scope of such experimental investigations.

A chick, not many hours old, will peck with fair but not complete accuracy at any small object which catches its eye. Here we have a reflex and responsive action. A stimulus is received in a sense-organ; an impulse is carried centripetally along ingoing or afferent nerve-fibres; certain nerve-centres are thrown into activity; and an outgoing impulse is carried by efferent nerve-fibres to muscles which are thus thrown into co-ordinated activity. It is probable that, on the first occurrence of such an action, it is purely automatic and is performed in virtue of the possession, by the chick, of an inherited organic mechanism. It is accompanied by, but not guided by, consciousness. Such guidance, however, soon becomes evident. Throw to a chick two or three days old half a dozen caterpillars, some of them common "loopers," others yellow and black "cinnabars." In the absence of previous experience they will be equally seized. But the loopers will be swallowed, while the cinnabars will be dropped. Repeat the experiment

next day. The loopers will be gobbled up at once. The cinnabars will remain almost, if not quite, untouched. An association has been formed between the sight and taste in the two cases. Consciousness is no longer merely an accompaniment of the action. It controls; enforcing the action in one case, inhibiting or restraining it in the other. It is probable that in the higher parts of the brain there are special centres, the physiological functioning of which is associated with this conscious control. Such activities of the chick, first those which are merely responsive and automatic, secondly those which are under conscious control, exemplify a wide range of activities both in animals and man.

Let us note the scope of the experimental work that they suggest. First, there is the nature and range of stimulation of the nerve-endings in the sense-organ. Secondly, there is the nature and rate of transmission of the impulses along the nerve-fibres afferent and efferent. Thirdly, there are the nature and localisation of the activities of the automatic centres, and the time occupied by their peculiar functioning. Fourthly, there is the physiological and psychological investigation of the nature and mode of origin of the consciousness which accompanies the movements of parts of the body during response. Fifthly, there are the conditions, psychological and physiological, of association. And sixthly, there is the mode of application of the control, and the localisation of specialised control centres, together with the estimation of the time-element in control.

All of these have been made the subject of careful and systematic inquiry by the method of experiment. In all cases such experimental investigation has led, if not to brilliant positive results, at all events to salutary acknowledgment of ignorance. Difficulties of interpretation abound. Nowhere are these difficulties greater than in the investigation of the physiology and psychology of colour-vision. Take a dozen individuals, and get them successively to indicate by means of the cross-fibres of the spectroscope how far they can see along the spectrum, first in the direction of the extreme red, then in the direction of the extreme violet. You will find marked differences. Perhaps one will show a quite unusual amount of variation, and you will probably find by other tests that he is colour-blind. Is this variation in the retina or in the visual centre of the brain? It is well known that the psycho-physiology of vision is still a matter under discussion. One of the difficulties seems to arise from the fact that what is physiologically complex is psychologically simple. Purple gives a simple psychological sensation; but it is due to a combination of physiological impulses, the coalescence or synthesis of which is, so to speak, below the threshold of consciousness. One cannot, or I cannot, psychologically analyse purple into its constituents, as one can analyse a musical chord. There is still a wide field for research in the psycho-physiology of sensation.

An important line of investigation, which has now been followed up for many years, deals, not with differences of kind or of quality in sensation, but with variations in intensity. Given a stimulus which excites sensation; now diminish it, on the one hand, until it ceases to excite sensation, and increase it, on the other hand, until it reaches a maximum of sensation. Then formulate the law which shall express the relation which increase of stimulation bears to the increase of sensation. The results of Weber's researches went to show that we must look not to the absolute, but to the relative increments of stimulus; and Fechner, extending and generalising Weber's results, formulated the law of the relations thus:—When the stimuli increase in geometrical progression, the sensations increase in arithmetical progression, or the sensation is proportional to the logarithm of its stimulus. Concerning this law, the exactitude and range of its applicability, and its philosophical *raison*

d'être, there has been much animated discussion, into which I do not propose here to enter. Suffice it to say that if we represent by a curve the rise of sensation from the threshold where it first dawns, to its maximum, the law seems to hold good only for the mid-region. Various methods of experimentation are employed. Weber and Fechner employed chiefly the method of tabulating the just discernible differences in sensation, of increasing, that is to say, the intensity of the stimulus, and noting when this increment is just perceptible. Others, using larger intervals, have employed the method of estimating equal increments. Others, again, have constantly doubled the stimulus and noted the change in sensation. In all cases it must be remembered that what we are really dealing with is the perception of the relations between certain given sensations. This is a fact too often lost sight of. We have to infer from these relations the intensity-curve in sensation.

In addition to experimental investigations concerning the qualities and intensities of sensory elements in consciousness, there are others which deal with the feeling-tone, that is, the pleasurable or painfulness of the sensation. Here with increase in the stimulus there is a rapid culmination of tone to the pleasurable maximum, after which it falls off pretty rapidly, and further increase gives rise not to pleasure, but to pain.

Researches on the rate of transmission of impulses along the afferent and efferent nerves may be regarded as mainly physiological. Suffice it to say that the rate is about 120 feet per second for ingoing impulses, and about 110 feet per second for outgoing impulses. Transmission in the spinal cord appears to be less rapid.

The results of experimental investigations on the localisation of function in the brain appear to justify the hypothesis that the automatic centres—or the centres concerned in merely organic response—are quite distinct from the control-centres, which are probably restricted to the cerebral cortex. It is a good working hypothesis that the centres which minister to control are the seat of those molecular disturbances which are concomitant with consciousness. Consciousness apart from control would be a mere epi-phenomenon of no practical use to the organism. It is scarcely necessary for me to do more than remind the reader of the conspicuous success which has crowned the efforts of those who have patiently and systematically applied the experimental method to the localisation of the centres of motor control. The motor regions of the hemispheres have now been mapped out with considerable exactitude. The centres of motor control in this region would seem to play down, so to speak, along the specialised channel of the "pyramidal tract," upon the lower automatic centres enforcing or inhibiting, as the case may be, their activity. They would seem to be developed on a secondary arc—the arc of control—superposed upon the lower reflex or responsive arc with its automatic centres. Sensory centres in this arc of control would seem to be, as might well be expected, less definitely restricted in position, as they are also more difficult of investigation. In all this field of research, as in the transmission of impulses, we are experimenting more on the physiological than on the psychological side of psycho-physiology.

When we come to association, very little that is exact and assured is known of the physiological aspect. It is said that association tracts—that is, groups of fibres connecting together the several centres in the cerebral cortex—are almost, if not quite, absent at birth, and are established during the development of experience, which may well enough be so; but what may be the physiological conditions of their development, we can at present only guess. On the psychological side much has been written on association; and in recent times Mr. Francis Galton, followed by Trautscholdt and others, have carried out experiments with the object of estimating the time that

elapses between the reception of a simple impression and the occurrence of a simple idea suggested thereby. Such time would seem to be about three-quarters of a second.

Much attention has been paid to what is termed "reaction time"; that is, the time which elapses between a given simple stimulation and the resulting responsive motion. This was found by Lange to vary according as the person who is being tested directs his attention to the expected sense-impression or the anticipated motor response. In the case of a simple response to a visual stimulus, the reaction time in the former case is rather more than one-fourth of a second, but in the latter case only about one-sixth of a second. Practice tends to shorten the time, while fatigue lengthens it. A pre-motory signal just before the stimulation markedly shortens it. Other experiments have been conducted with a view to ascertaining the time taken in simple cases of discrimination. This, too, varies very much with practice; and it is questionable whether the shorter time-values measure an act of discrimination properly so called. This part of the subject is full of difficulties in the interpretation of the results obtained.

In the Harvard psychological laboratory interesting researches have recently been carried out under the direction of Prof. Münsterberg. One of these deals with memory. Experimental results seem to show that a series of presentations offered to two senses at the same time, *e.g.* to sight and hearing, is much more easily reproduced than if given only to sight or only to hearing—a fact of educational value. Another series of experiments deals with the effect of attention. The unexpected result is reached that all stimuli appear relatively less when the attention is from the outset directed to them, as compared with stimuli received while the attention is otherwise occupied, *e.g.*, with simple addition sums. This result and the methods employed in the investigation are likely to undergo criticism.

Enough has now been said to indicate the kind of work on experimental lines which is being done in psycho-physiology. In England, while valuable researches have been prosecuted in cerebral localisation, comparatively little has been done on the lines which are followed up in the German and American psychological laboratories, though Mr. Francis Galton's valuable psychometric observations have been based on somewhat similar methods. I think that this is a matter for regret. It is true that both methods and results need perfecting and clarifying. That is generally so in pioneer work. It is true that it is mainly to elementary and simple psychological processes that the methods are applicable. But we must begin with the simple, however desirous we may be of reaching a knowledge of the complex. It is true that such experimental work cannot take the place of introspective observation. But may it not be used to supplement the older method? English psychologists have done such good work on the old lines, that one could wish that the newer methods should be given a fuller and more extensive trial. Somewhat is indeed being done, and there are signs of improvement. We need also systematic work in zoological psychology. Observations which I have made on newly-hatched chicks and ducklings, stimulated thereto by suggestions from my friend Mr. T. Mann Jones, have convinced me that there is a wide field for careful experimental work on the instincts and the dawning phases of intelligence in young animals. We must employ the experimental method if we would make further advance in the study of the mental faculties of animals. Is it too much to hope that the time is not far distant when there shall be established in England chairs of zoological and experimental psychology, the occupants of which shall have the direction of adequately equipped laboratories wherein systematic observations, on the lines I have above indicated, may be conducted?

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