PHOTO-ELECTRIC RECORDS OF THE COLOUR CHANGE IN *FUNDULUS HETEROCLITUS*

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(With Two Text-figures.)

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The colour change in *Fundulus* is produced by an alteration in the size of its chromatophores, caused by impulses in special nerve fibres running to them. According to Parker (1934 a, b, and elsewhere) the nerves produce their effects not directly, but by chemical transmitters ("neurohumors") of some kind. The movements of the chromatophores are very rapid, although they are not, as in the cuttlefish and squid, due to muscle fibres pulling the chromatophores out, or allowing them to relax elastically.

The present experiments were made in order to find how accurately the colour change could be recorded, and how rapid it actually is. One hundred fishes were brought from Boston by the Cunard White Star Line, and sixty-three arrived in London safely. Prof. G. H. Parker had been kind enough to advise the Company on their treatment. They were kept in the laboratory in running tap water in a large sink, they were fed on sea mussels twice a week, and the majority remained in good condition for months, in spite of the hot weather. The larger fishes were used for the experiments, as their backs presented a greater area for examination.

The method used was analogous to that described by Hill and Solandt (1934) for recording colour changes in *Sepia*. The experimental fish was placed in a glass tube, through which oxygenated water could run from an aspirator bottle on a shelf above. The tube was too short, and too narrow, to allow the fish to move about, but it remained comfortable and in good condition, seldom struggling, and appeared to take an intelligent interest in what went on outside. The water flowed in the direction from head to tail, either slowly and continuously, or with intervals in which it was stopped by turning a tap. The temperature was measured in the water behind the fish.

A beam of light from a Pointolite lamp was concentrated on the fish's back, and the illuminated area was approximately focused on, and occupied the whole sensitive area of, a rectifying photocell which was connected to a Moll galvanometer. Just beneath the glass tube containing the animal, and where the latter could see it, was a large card covered with matt black paper which could suddenly be removed by revolving around a screw: when the black was removed a white background
The change in background occupied a fairly small fraction of a second, and caused an immediate movement of the galvanometer. The new zero was read, and the moment at which it was reached was recorded with a stop-watch. The animal then changed colour, attempting to match the background, and the galvanometer continued to deflect. Reading continued for 40–60 sec., by which time the change was complete. Darkening on a dark background and lightening on a light background were both recorded; readings were made every 5 sec., and the means taken for about a dozen changes in either direction.

The results are plotted in Figs. 1 and 2. The first reading was at about 1·3 sec. when a Moll ordinary galvanometer was used, or at about 0·5 sec. with a Moll
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micro-galvanometer. The extra speed of the latter proved to be unnecessary, while the extra sensitivity of the former was an advantage. Experiments were made on several different fishes and at various temperatures. At 27°C in one fish the colour changes were too quick to read accurately; in another at 8–9°C they did not occur at all, though they were obvious at a higher temperature. A very interesting result was obtained when the fish was allowed to exhaust the oxygen in the water around it, the flow having been stopped. The animal began to "pant" but remained otherwise apparently quite normal, following with its eyes what happened outside; the colour change, however, soon diminished and in 15 min. was entirely absent.

Fig. 2. As Fig. 1 but lower temperature. Note that in Figs. 1 and 2 the lightening process is sometimes quicker and sometimes slower than the darkening process.

Within 3 min., however, of starting the flow of oxygenated water again the colour change was normal in size and character. It was noticed in general that the colour change was quicker and more obvious when the water was well oxygenated.

The experiments have not been extended, except casually, but it is clear that the response of the chromatophores in *Fundulus* can be treated just like reflex muscular contraction. The "pulse" of response (analogous to a twitch or a short tetanus) could be examined when the background is altered for a short interval only: "summation" of such "pulses" could be observed when the background is altered in recurring intervals. The effects of pharmacological and other agents on the form of the response could be examined. The colour sense of the fish might be studied. The method is simple and allows considerable variety in its application.

SUMMARY.

The colour response of *Fundulus heteroclitus* to change in its background has been recorded photo-electrically. Temperature and oxygen supply affect its magnitude and velocity.

REFERENCES.
