

In referring to his outstanding discovery Priestley has modestly recorded a reflection often recurring in the minds and writings of those interested in the relation of cause to effect when he says "it provides a striking illustration of a remark I have more than once made in my philosophical writings and which can hardly be too often

repeated, namely, that more is owing to what we call chance than to any proper design or preconceived theory in this business". That reflection remains legitimate, but must be accepted only in conjunction with Pasteur's dictum that "in the field of observation chance favours only those who are prepared".

M. O. F.

Locomotion of Fishes.

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THE muscular movements of fishes have been studied from a very early time, and the researches of Borelli,¹ Pettigrew,² Maurey³ and Breder⁴ deserve special mention in this connection. In spite of the wealth of literature available on the subject (see Breder for bibliography) the exact significance of these movements has only been realized during the current year as a result of the careful work of Dr. J. Gray⁵ in the Laboratory of Experimental Zoology, Cambridge. It was believed that the fins of fishes are the main organs of locomotion, and that the fish impels itself forwards by the tail and the caudal fin. These conclusions seem to have been based on erroneous impressions, for the eye observes only the movements of the tail relative to the head instead of observing its motion in relation to the background of the fish. Dr. Gray has, however, recorded photographically the movements of a number of fish against a scaled background, and these records have enabled him to analyse the nature of the part played by different organs in the locomotion of fishes.

Superficially the motions of various types of fish appear to vary considerably from one kind to another. For example, the most conspicuous features of a moving eel are the waves of curvature which pass along the length of the body from head to tail. In the fast-moving mackerel the visible movements appear to be due to transverse strokes executed by the posterior end of the body across the axis of motion. Dr. Gray was able to demonstrate that the waves of muscular contraction occur in almost all fishes, but that these vary greatly in speed of propagation, amplitude and frequency. As in eel, the forward progression of fishes is mainly due to the waves of muscular contraction. It has been

experimentally demonstrated by Breder in the case of *Scardineus erythrophthalmus* that it makes no appreciable difference in the "cruising" speed of the fish whether it moves with the caudal fin intact or with the caudal fin carefully amputated. These observations have been confirmed by Gray by the removal of the caudal fins of the rudd, the perch, and the whiting.

In a fish moving forwards the waves of muscular contraction start from the anterior-most region of the body, and it is found that the speed of propagation of the waves is too low to be controlled by the rate of conduction of a simple nervous impulse. The forward propulsion of the fish is due to the fact that its leading surface faces obliquely backwards relative to the head of the fish and that it moves at an angle to its own direction of motion. It is thus seen that so long as the leading surface is moving at an angle to its own path of motion, there will be a pressure exerted at right angles to the surface, and so long as the leading surface is directed obliquely backwards relative to the head of the fish, the pressure will be directed obliquely forwards. "The magnitude of the forward thrust depends, among other things, on (a) the angle which the surface of the fish makes with its own path of motion, and (b) on the angle between the surface of the fish and the axis of forward movement of the whole fish, (c) on the velocity of transverse movements of the body." Dr. Gray has shown that the underlying mechanism of propulsion of a typical fish is similar to that of a typical screw propeller. In this movement it is seen that each point on the body of the fish travels in a horizontal figure of 8 relative to a transverse axis which is moving forwards at the same average velocity as the whole fish.

