past the surface of an active fish is totally different from that of a rigid surface; the water flows smoothly past the undulating surfaces and is subjected to well-defined acceleration. It would be significant if a flow of this type tended to reduce turbulence. Similarly, it would be of great value to know more about the propulsive effect, considered by Garrick[5], of an actively oscillating surface hinged to the hinder edge of an aerofoil. If the flow past the body of an actively swimming salmon proves to be laminar, we can accept Houssay's estimate of muscle-power without asking anglers to believe that the fish cannot travel at 20 m.p.h.

The object of these comments is not, in any way, to detract from the value of further information concerning the propulsive powers of large whales or the hydrodynamical properties of rigid surfaces, but to emphasize the peculiar importance of studying forms, such as the dolphin, where the ratio of body surface to muscle weight seems to render them much more impressive models of submarine design. At the same time, the situation seems likely to remain obscure until we know a great deal more about the hydrodynamical properties of oscillating surfaces, and have been able to measure the forces operating against the body of a living or model fish in a water channel. The whole problem seems to present an admirable opportunity for co-operative effort. The results of such an inquiry might or might not lead to the construction of faster or more efficient submarines; but in so far as they enabled us to measure the propulsive thrust of a fish's tail, they would have a very direct bearing on the design of efficient fish passes for salmon.

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Mr. Gawn has revived interest in Gray's[1] demonstration that the drag of a fast-moving small whale, treated as a rigid body, seems to demand far more power than its muscles could supply, even if the propulsive efficiency were 100 per cent. Clearly, the assumptions underlying the evaluation of the equation

$$\text{muscle power} = \frac{\text{drag} \times \text{speed}}{\text{propulsive efficiency}}$$

need reconsidering. We have recently published some work[2] which considers two of the factors: muscle power and propulsive efficiency.

(1) *Muscle Power*. Mr. Gawn follows Gray in using 0·01 h.p./lb. as the maximum mechanical power output of muscle—a figure based on the external work done during a 15-min. maximum effort by a rowing crew. But muscle-power cannot be expressed as a simple function of size, without taking into account the conditions under which the muscle is working, and in particular the rate of fatigue and muscular efficiency. Thus a man working a bicycle ergometer at maximum muscle efficiency can develop more than 0·02 h.p./lb. (from data given by Dickinson[3]) until the accumulating oxygen-debt ends the activity; while greater power still can be developed during a single flexion of the arm against a suitable load. This suggests that an animal capable of a higher rate of oxygen intake than man might develop greater power for a given time, or a given power for a greater time. We have suggested that the respiratory adaptations which enable whales to discharge their oxygen-debt quickly after long dives may also enable them to maintain an unusually high oxygen intake, and therefore power-output, when they are swimming near the surface and can blow frequently. This idea is supported by Scholander's[4] observation on a porpoise that both the vital capacity (relative to man) and the absorption constant were greater than in man. As for muscle efficiency, it is quite possible that the efficiencies achieved by man with the help of well-designed machines may occur in whales during normal locomotion, because the loading of their muscles will be high and the rate of contraction low.

(2) *Propulsive Efficiency*. We have shown that the swimming movement consists of a vertical oscillation of the tail (that is, region posterior to the dorsal fin) and a continuous adjustment of the angle of attack of the flukes to give a forward thrust throughout the tail cycle. The dynamics of such a system have been worked out assuming the flow around the flukes to be stable; but the efficiency then obtained is improbably low and indicates the need for further work, observational (particularly on the relation between forward speed and oscillation frequency) and experimental. The comments of a marine engineer on this method of under-water propulsion would be of great interest.

We believe that the other problem raised by Mr. Gawn—heat loss—is much less difficult. Blubber is fundamentally similar to a terrestrial mammal's skin, and blood vessels run through the thick fat layer (hypodermis) to form a plexus and capillary loops a few millimetres from the surface. Control of the flow of blood through these vessels would provide for a considerable range of heat loss. Indeed, the problem is how to keep warm rather than how to lose excess heat, for we have shown that heat loss by conduction through the blubber alone is such that a 14-cm. layer would be needed to reduce basal metabolism to the level characteristic of most mammals. Perhaps most whales need to keep swimming in order to keep warm.

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Bacterial Flagella and Motility

In dark-ground microscopy with the sun as light-source, motile bacteria, when swimming fast, show a tail, as in the top left-hand photograph reproduced. This tail is occasionally seen to untwist into a number of wavy threads which appear to remain attached to the periphery of the bacterial body for a while and then float away[1,2,3]. When such preparations are dried, the wavy threads can be stained with so-called flagellar stains, and hitherto they have been regarded as 'flagella' or motor-organs. Motility of bacteria is thought to be due to activity