methods of internal tagging to the herring fisheries of Norway and Iceland (where the greater use of fish-processing plants makes such methods possible), particularly in view of the growing evidence of large-scale seasonal migrations between north Iceland and Norway. Special arrangements were recommended for securing further information on the occurrence of these herring shoals with the help of all vessels of the member countries which operate in these northern waters.

Among other aspects of herring research, developments in the use of echometers were discussed, while several papers were read on the influence of the fishing on the herring stocks. Here the absence of really adequate statistics was felt, and particularly in view of the meeting of the Food and Agriculture Organisation at The Hague in August 1949, it was recommended that all countries take steps to provide standardized statistics of unit catches, so that an adequate watch can be kept on the signs of stock changes in the various fisheries and their possible causes. It was felt by all the representatives that so valuable have been the two herring meetings, and so great is the need for the closest international collaboration, that the various herring experts should now have regular opportunities to meet. All the area committees concerned with herring problems endorsed this feeling, and the Council agreed to establish a herring committee forthwith.

The scientific proceedings closed with another special meeting to review research problems in the fields of the commercial fisheries for Crustacea and Mollusca. A large number of interesting papers were circulated and discussed, and it was decided to adjourn the meeting until the next session of the Council at Copenhagen in 1950, so that progress and problems could be further discussed.

Apart from *ad hoc* meetings such as these, the greater part of the work of the Council is done by the standing committees dealing with research in the various regions and in certain special fields of study. During these meetings the progress of European fisheries research during 1948–49 was reviewed, programmes for 1950 were discussed and arrangements made for their co-ordination where necessary. In particular, the preliminary results of the international hydrographical–biological surveys of 1948 and 1949 were discussed, and arrangements made for a combined long-term fisheries research programme for the North Sea and the waters to the north-west and north-east. The arrangements for publishing the long-established *Bulletins Hydrographiques* and the much more recent *Annales Biologiques* were also reviewed, as were the arrangements for collecting, standardizing and publishing statistics of the various fisheries (*Bulletins Statistiques*) in which the advice and experience of the Fisheries Division of the Food and Agriculture Organisation were welcomed. The special international programme of salmon tagging was extended for another three years, and a co-ordinated investigation of salmon migrations around the Irish coast was recommended.

Great interest was shown during the meeting of the Southern North Sea Committee in Dr. Å. V. Tåning's account of the large-scale experimental transplantation by the Danish Government of plaice to the Dogger Bank area. So far, one million plaice have been transplanted, and the results of this major experiment will be awaited eagerly by all marine workers who are aware of the earlier experiments in this field.

The following committee chairmen were elected for the year 1949–50: *Consultative*, Dr. R. S. Clark; *North-Eastern Area*, Mr. G. Rollefsen; *North-Western Area*, Dr. Å. Vedel Tåning; *Atlantic*, Prof. Jean Le Gall; *Northern North Sea*, Dr. C. E. Lucas; *Southern North Sea*, Mr. R. S. Wimpenny; *Transition Area*, Dr. E. M. Poulsen; *Baltic Area*, Dr. Chr. Hessle; *Hydrographical*, Mr. Helge Thomsen; *Plankton*, Mr. F. S. Russell; *Statistical*, Dr. Nils Rosen; *Salmon and Trout*, Prof. K. Dahl; *Whaling*, Dr. N. A. Mackintosh; *Herring*, Dr. W. C. Hodgson; *Finance*, Dr. K. A. Andersson.

During the course of the discussion, various social gatherings were arranged, together with excursions, including a visit to the laboratory of the Scottish Marine Biological Association at Millport. Following the meeting, a number of the Continental delegates and experts took the opportunity to attend the joint meeting of the Challenger Society for the Promotion of the Study of Oceanography, on the invitation of the Society and the Marine Laboratory of the Scottish Home Department, Aberdeen.

AQUATIC LOCOMOTION

4416

THE possibility that some aquatic animals may possess a propulsive mechanism of greater efficiency than that of a torpedo or submarine was the subject of a stimulating discussion at a joint meeting of Sections D (Zoology) and G (Engineering) at the Newcastle meeting of the British Association.

Prof. L. C. Burrill first described the distribution of velocity and pressure around a smooth streamlined body such as a fish or a submarine, deeply immersed in a fluid and advancing with uniform velocity. In such circumstances there is a positive or increased pressure on the forward part of the body which tends to retard the motion, and a similar increased pressure on the aftermost parts tending to assist the motion. On the middle part of the length there is a region of decreased pressure; but, owing to the shape, the fore and aft components here are small. In an ideal fluid, the net fore and aft component of the pressures and sub-pressures would be zero; but in an actual fluid such as water, when viscosity is present, there may be a small positive resistance retarding the motion, known as the pressure resistance. This is, however, usually very small when compared with the resistance caused by the rubbing of the fluid against the surface of the body, which is known as the skin-frictional resistance.

Prof. Burrill then proceeded to discuss the mechanism of this frictional resistance. He described the existence of a layer of fluid close to the surface of the body within which the forward velocity of the entrained fluid diminishes, rapidly at first and then more slowly, until a zone is reached where the forward velocity is very small. The thickness of this layer increases from forward to aft along the form. For low speeds of advance and short lengths of body, the flow within this boundary layer may be completely laminar, and successive layers of fluid appear to slide over each other smoothly and steadily. This type of flow may persist up to Reynolds numbers (VL/ν, where V is velocity, L is length of body and ν is kinematic viscosity (viscosity/density)) of about 5×10^6. For greater speeds and longer lengths of surface, the flow within the boundary layer is usually laminar for only a short length at the forward end.

This is followed by a short region in which the fluid is in a state of transition from laminar to turbulent flow. Beyond this the flow within the boundary layer becomes almost entirely turbulent, apart from a very thin laminar film, or laminar sub-layer, immediately in contact with the surface.

The thickness of this laminar sub-layer diminishes along the length towards aft, and if the roughness of the surface is such that the peaks of local excrescences project through this film, then an additional effect is present, which may be termed roughness effect. In these circumstances, the particles of fluid are tripped by the peaks of the excrescences, and small eddies are formed. Complete turbulence may then exist within the boundary layer, and when this occurs the resistance is governed by considerations of kinetic energy rather than viscosity effects, and varies as the square of the speed. As the local velocity over a considerable length of the middle part of the form is increased relative to the general stream velocity, and only for short lengths at the forward and after ends is the local velocity below the speed of advance, the mean velocity of rubbing is slightly greater than the velocity of advance. The frictional resistance is therefore slightly greater than that of a flat surface of the same length and area travelling at the same speed. This effect, which may amount to about ten per cent in some instances, is known as the form effect on frictional resistance.

Outside the boundary layer, the fluid is in streamline flow, and the pressure and suctions are transmitted through the fluid in the usual manner for potential flow. The point in the length at which laminar flow ceases is dependent mainly on the local Reynolds number, measured by Vl/ν, where l is the length from the entrance. Towards the after end of the form, a position may be reached where the fluid particles have been slowed down to such an extent within the boundary layer that there is not sufficient kinetic energy to carry the boundary layer through to the zone of increasing pressure at the tail end, and in these circumstances reversal of the flow may occur, resulting in separation and serious losses due to eddy shedding.

An application of the principles described by Prof. Burrill to the movement of fish was then made by Dr. E. G. Richardson and Mr. G. E. Gadd. Dr. Richardson described some model experiments designed to throw light on the resistance of fishes in motion. The first set of experiments was intended to show that there is nothing in the nature of the shape or bodily covering (scales and mucus) of a fish which could give it when 'coasting' a less resistance than that of a wooden model of the same form. This was shown by comparing in a tank the rates of fall of dead fish, loaded with weights, and wooden models made accurately to the same shape. No difference in the trajectories of animal and wooden model could be detected.

After a study of the theory of the method of propulsion adopted by the majority of aquatic animals, that is, sinusoidal motion of the whole or a portion of the body, this was also studied on a model scale, using a flexible 'flag' hanging vertically in a small wind tunnel and agitated in periodic oscillation at its upper end. As the model fish was attached to a force balance at the nose, it was possible to measure the propulsive force derived from different frequencies and amplitudes of oscillation against a current the value of which could also be varied through the speed control of the tunnel. Results showed how the resistance or propulsive force varied with the speed of waves along the body, relative to the speed of the stream. The 'resistance' of a fish can be referred to in terms of these two speeds, in the same way that the 'resistance' of a screw propeller is a function of revolutions and speed of advance.

Mr. Gadd dealt with certain hydrodynamic aspects of the swimming of fish. A steadily swimming fish transmits a wave of increasing amplitude backwards along its body at a speed greater than the forward speed of the fish. Usually the tail moves much more than the rest of the body, but one can imagine for convenience a fish in which the body wave is of constant amplitude. It might be supposed that such a fish would experience much the same thrust as would occur for a rigid body, bent into the wave form, and pushed backwards at the speed at which the wave moves through the water. This, however, may be untrue because not only does the fish differ in its motion from the rigid body at the ends, but also the movement of the surface of the fish relative to the water differs from that of the surface of the rigid body.

This latter difference may be important because it may affect what is known as 'flow separation'. Separation is said to occur when the flow past a body does not conform smoothly to its shape but forms an eddying region behind it. Its occurrence can be greatly affected by surface conditions. Hence, although the rigid body pushed backwards would experience separation from its forward inclined surfaces (and over areas from which separation occurred the pressure would be reduced, producing a forward thrust), it is not certain that separation in general occurs over the body of a fish. In the particular case of fishes like the eel, which have long, continuous anal and dorsal fins, some separation must occur, since the flow could not otherwise negotiate the sharp edges of the fins. Hence with these fish the propulsive thrust is probably primarily the result of separations from the forward inclined surfaces.

In general, however, separation does not necessarily occur. In attempting to analyse what would happen if it did not, one may consider the simple case of a slender pointed-ended body without fins executing small-amplitude fish-type motions the amplitude of which is greatest at the rear. One finds that no net thrust occurs: there is a propulsive force associated with lateral accelerations of segments of the body which is balanced by a drag associated with the rearward tapering. Accordingly, if a small tail fin were fitted to this body—when it would somewhat resemble a mackerel, the body of which is pointed at the rear—most of the propulsive thrust would come from the fin, acting like the wing of a bird. Hence, if no separation occurs with a mackerel, most of its thrust probably comes from its fins (but note that the small saw-tooth fins over top and bottom of the body at the rear may cause separations). If the body considered above, instead of being pointed at the rear, were flattened laterally and fitted with a tail fin, so that it somewhat resembles a 'typical' fish, some thrust would probably come from the body as the drag forces arising from the rearward tapering would probably be reduced. Hence 'typical' fish probably obtain thrust from their bodies as well as their fins, whether separation occurs or not.

The present state of knowledge concerning the speed and available horse-power of a variety of aquatic animals was reviewed by Prof. J. Gray, who stressed the urgent necessity for more extensive and trustworthy information concerning the maximum speed of fish of known size. The behaviour of fish, as observed photographically in the laboratory, suggests that a trout 20 cm. long can only sustain a speed of 5 miles per hour for a relatively few seconds. On the other hand, the powers of acceleration of the animal are remarkably high—starting from rest, the fish may attain their maximum speeds in a fraction of a second. A sustained speed of five m.p.h. agrees with what is known concerning the available horse-power of the muscles and the resistance of the body of the animal as determined by Dr. Richardson. In the case of the dolphin, however, the speed of the animal appears very greatly to exceed that calculated from a reasonable estimate of muscular horse-power.

No final conclusions can be derived from this discussion; but the British Association is to be congratulated on a very successful attempt to concentrate attention on what is a very interesting, and possibly important, border-line subject.

10/2

OBITUARIES

Prof. Alfred S. Barnes

J. Langton

The death on November 11 of Alfred S. Barnes removes another survivor of a former generation of the teachers of the Manchester Municipal School of Technology: most have passed away. The School—then the largest and best equipped in Great Britain—was opened in 1902; Barnes was appointed in 1901 as professor and head of the Department of Physics and Electrical Engineering. There were seven other professors, of whom F. Jackson Pope (afterwards knighted) and J. T. Nicholson may be specially mentioned. Though Barnes had not the scientific equipment of these two, his industrial experience, his acumen and regard for precision made him a good organiser. The Department developed; the number of students taking the evening part-time courses increased, partly by the diversity of the subjects catered for. In those early days all the electrical subjects taught in the day department were required for the associateship diploma of the School.

Barnes believed in amplifying the teaching by external lecturers from the industry. William Cramp and Julius Frith (consulting engineers) strengthened the day teaching of electrical design. Of others, Miles Walker succeeded Barnes as professor, and A. P. M. Fleming (now Sir Arthur Fleming) lectured on insulation.

In 1905, the day school became the Faculty of Technology of the University of Manchester, and Barnes was elected to the chair of electrical engineering. He was a good speaker and a power in the Faculty and in the Senate. He was of imposing presence, had clear-cut features, and on account of his hair brushed well back was affectionately called by his students "'Airy Alf".

In his desire for precision he encouraged the late A. E. Moore to develop a standardizing laboratory, which was the best equipped outside the National Physical Laboratory. Barnes gave the present writer charge of a high-tension laboratory; thus was started the first 'School' in the country for high-tension technics (later high-voltage engineering).

Barnes's researches were of a practical kind. A joint paper on "Fuses" read at the Institution of Electrical Engineers was awarded a premium. Travelling by train from his Buxton home, he observed corrugations on the rails. Investigating the causes of their formation, he submitted another paper to the Institution. Near Buxton he discovered some flints which appeared to be worked by prehistoric man: further investigations led to a paper presented to the Manchester Literary and Philosophical Society. Even after he had retired, his interest in anthropology took him to many places, including France and Ceylon.

Barnes resigned his professorship in 1912 to become staff inspector at the Ministry of Education, retiring in 1928. He initiated the short courses for engineering teachers, organising them for many years. Even after his retirement he attended the Oxford Summer Course for Engineering Teachers, acting as chairman for about ten years. Barnes was largely responsible for the inception of National Certificates in Engineering. He was a religious man, and often would give talks on spiritual matters and the heritage of humanity to Brotherhoods in and around Manchester. Such were the facets of his life's work.

J. L. Langton

Mr. Willoughby P. Lowe

816

N. B. Kinnear

By the death of Willoughby P. Lowe there passes one of the last of the professional collectors who worked so successfully on behalf of the British Museum.

Willoughby Prescott Lowe was the son of the Rev. Edward Lowe and was born at Tyler's Green, Buckinghamshire, on December 10, 1872. From his childhood he was interested in natural history, and at the age of sixteen went to Colorado to join his brother on a sheep-run. There he remained for nine years and had ample opportunity for engaging in his favourite pursuit. In 1897 he returned to England and ten years later went to the Philippines on behalf of the British Museum to collect birds and mammals. Thereafter he became a professional collector and undertook some seventeen collecting expeditions, on behalf of the British and other museums, to many parts of the world. Most of his collecting, however, was done in Africa, and it is safe to say that he contributed more specimens from that continent to the British Museum collections than any other collector. He accompanied Abel Chapman and Admiral Lynes to the Sudan, and later spent two years with Lyres collecting in the Darfur Province of the Sudan. He also went with him to Tanganyika in search of Cisticolas.

By special arrangement Lowe was able, on two separate occasions, to visit the west coast of Africa on H.M. gunboats, and at different times he made expeditions to the Gold Coast, Gambia and French Guinea. In company with Dr. David Bannerman he made an important collection in Tunisia and, some years later, in January 1931, went as assistant to Colonel Meinertzhagen on a trip to the Haggar Mountains in the Sahara. Lowe took part in the Anglo-American expedition to Madagascar and on four different occasions made collecting trips to Indo-China with M. Jean Delacour. In 1922 he published an interesting account of his earlier expeditions entitled "The Trail which is Always New", and five years later "The End of the Trail", in which he completed the story of his collecting life.

Lowe's quiet and unassuming nature endeared him to his friends, and as a travelling companion he was always helpful and completely unselfish. After he retired from active collecting he worked for a number of years as honorary curator of the Royal Albert