New Studies of Sun-fishes made during the "Dana" Expedition, 1920.

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[The *Dana* is a four-masted motor schooner of 550 tons, belonging to the East Asiatic Company of Copenhagen. His Excellency H. N. Andersen, director of the company, generously placed this vessel at the disposal of the Danish Committee for the Study of the Sea for a cruise in the Atlantic.]

THE sun-fishes (Mola and Ranzania) are undoubtedly among the most remarkable creatures which inhabit the oceans. By their peculiar shape, altogether unlike what we are accustomed to find in fishes (Figs. 1–3), their divergence in point of internal structure, and the considerable size which the best-known species attains, they have from ancient times attracted the attention of naturalists.

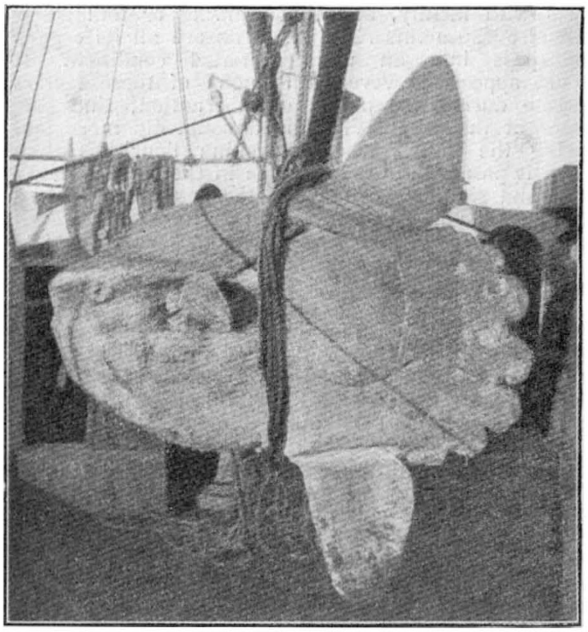

FIG. 1.—The *short* sun-fish (*Mola rotunda*). Length, 2·11 metres; weight not noted, probably about 500 kilos. (From Murray and Hjort's "Depths of the Ocean.")

Two species were known with certainty to occur in the North Atlantic: the *short* sun-fish (*Mola rotunda*, Fig. 1) and the *oblong* sun-fish (*Ranzania truncata*, Fig. 2). To these I am now able to add a third: *Mola lanceolata* (Fig. 3), a form the specific value of which has been questioned by recent authors. Though related to *Mola rotunda*, it is doubtless a distinct species, differing by the pointed tail and the number of fin-rays, as well as by several larval characters.

The oblong sun-fish attains a length of only two or three feet; the short sun-fish, on the other hand, is known to have reached a length of eight to ten feet or more, and a weight of more than a ton. It is thus one of the giants of the ocean. That the sun-fishes also possess gigantic strength is evident from a report of one of the Prince of Monaco's cruises in the Atlantic with the yacht *Hirondelle*, where we read that a large specimen—the same as that represented in Fig. 3—which was harpooned from a boat sent out from the yacht, almost pulled the boat under in its struggles

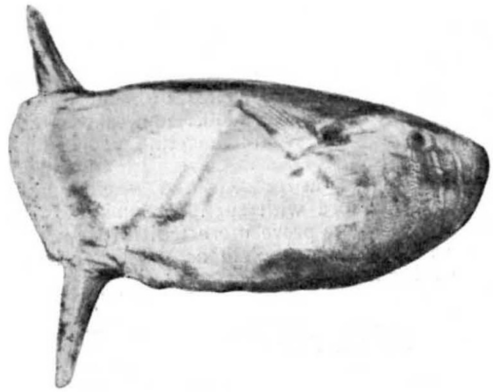

FIG. 2.—The *oblong* sun-fish (*Ranzania truncata*). Length, 0·65 metre. (From Beauregard.)

to escape. The sun-fish owes its strength to the powerful development of the muscles controlling the two large vertical fins (the dorsal and anal, shown in Fig. 1). On the other hand, the muscles generally composing the greater part of the body

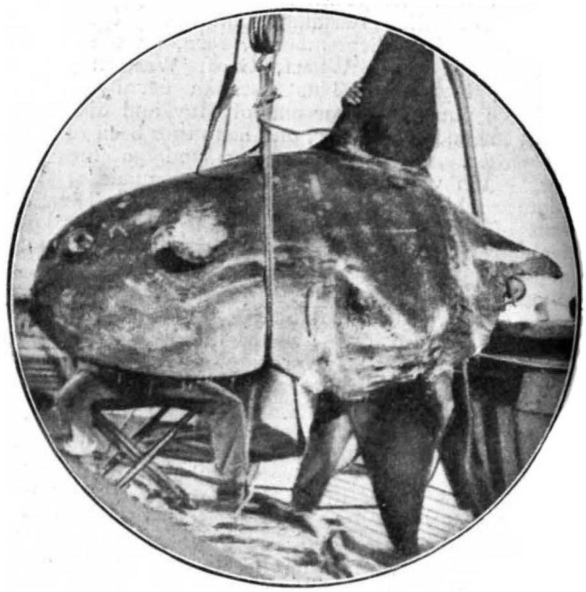

FIG. 3.—*Mola lanceolata*, a species related to the short sun-fish, but differing by the pointed tail. Length, 2 metres; weight, 285 kilos. (From the Prince of Monaco.)

in a fish, the great lateral muscles, are rudimentary in the sun-fish.

The short sun-fish (*Mola rotunda*) occurs comparatively frequently off the coasts of Western and Northern Europe, near the British Isles more especially in the summer, and in Danish waters during autumn; it has also been found near Iceland and off the northernmost coast of Norway (about latitude 70° N.). It is thus not difficult to procure specimens, and such are also to be seen in most museums. The oblong sun-fish (*Ranzania truncata*), on the other hand, is far more rarely seen in collections. It does not penetrate so far to the north as *Mola rotunda,* but has, nevertheless, been found occasionally in the waters of Western Europe and the British Isles, where its northern limit of occurrence appears to lie.

With regard to the habits of the oblong sun-fish (Ranzania) practically nothing is known. It may, however, be mentioned that it was on one occasion observed in enormous numbers at the surface of the water, at Martinique, in the West

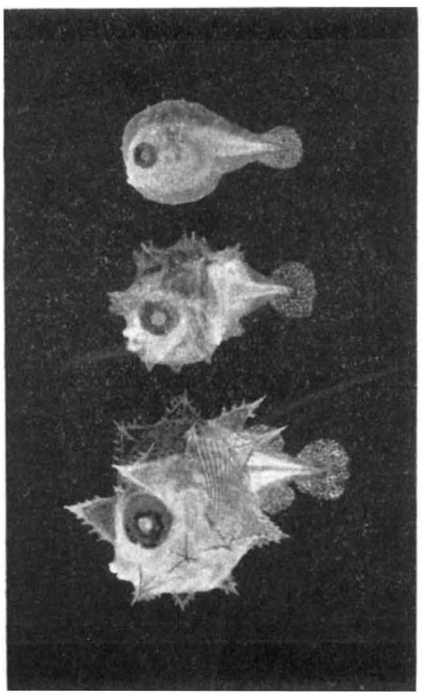

FIG. 4.—The *oblong* sun-fish (*Ranzania truncata*), larval stages. Length, *a*, 1·7 mm.; *b*, 1·8 mm.; *c*, 2·4 mm.; *a* hatched on board the *Dana* in the Sargasso Sea.

Indies. The short sun-fish is quite frequently encountered by mariners in the Atlantic. I have myself, on my cruises there, often seen it lying half sideways at the surface, with the tall dorsal fin projecting out of the water. It is not infrequently captured in the Mediterranean, especially during summer in the Straits of Messina, and it is known to feed on small forms of pelagic life. A fact of interest is that the larvæ of the fresh-water eel appear to be its favourite food. The stomach, when opened, will often be found to contain eel larvæ (*Leptocephalus brevirostris*) by the hundred. There can thus be little doubt that it is one of the eel's deadliest enemies. The sun-fishes appear to be highly prolific. In a specimen of *Mola rotunda* $1\frac{1}{2}$ metres long, for instance, the ovary was found to contain no fewer than 300 million small unripe ova.

The method of propagation of the sun-fishes, however, is unknown, and the tiny stages have not been identified in the case of any species. The collections made by the Danish Committee for the Study of the Sea have often brought to light larvæ which I had to refer to the sun-fishes, but it was impossible to determine to which species they belonged. On the trans-Atlantic cruise of the *Dana* in the summer of 1920, however, I succeeded in throwing light on the question, and was able to follow the

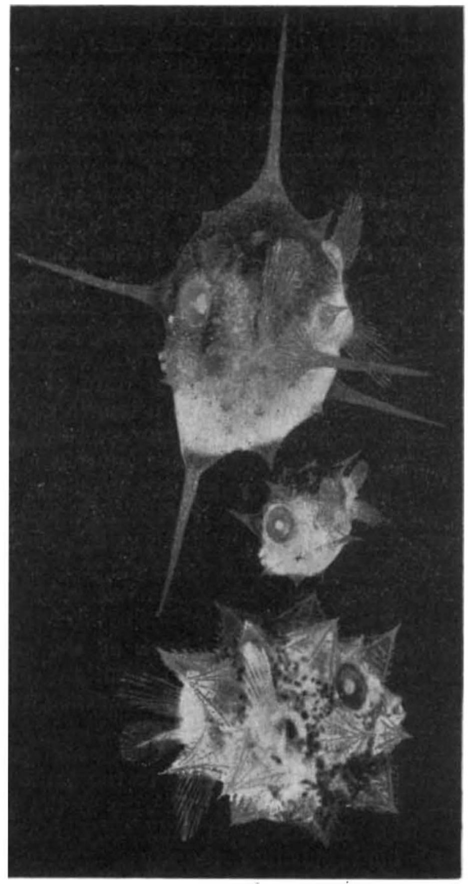

FIG. 5.—*Mola lanceolata* (*a* and *c*), *Ranzania truncata* (*b*): *c* larval, *a* and *b* post-larval stages. Length, *a*, 5·5 mm.: *b*, 3·5 mm.; *c*, 2·8 mm.: *a* and *b* same enlargement, *c* more enlarged. Note that the tail has disappeared in *a* and *b*.

development of two species for a great way back: in the case of one, to the egg itself. A full account of this needs a mass of illustration and proof material which would be out of place here. I will therefore merely give a few illustrations, reproduced from photographs, adding thereto some remarks on these larval forms, which, because of their odd appearance, are probably without parallel among fishes.

Fig. 4, *a,* shows a larva of the oblong sun-fish (*Ranzania truncata*), about 1·7 mm. long. It was hatched on board the *Dana* in the Sargasso Sea.

The eggs were found floating at a depth of scarcely 100 metres from the surface; they are small, transparent spheres, 1·3–1·4 mm. in diameter. It will be noticed that the larva, albeit clumsy to look at, nevertheless resembles an ordinary fish larva, with the usual strong tail. During the course of development, however, the tail is soon reduced, while the dorsal and anal fins, on the other hand, grow out strongly (see Fig. 5, *b*). It is precisely this reduction of the tail portion which gives the sun-fishes their remarkable, as it were truncate, appearance, as seen in Figs. 1 and 2. At a first glance it would appear as if the third species (*Mola lanceolata*) had retained the primary pointed tail (see Fig. 3). This is, however, only apparently the case; on studying the development, it will be seen that the primary larval tail here likewise soon disappears, and that the pointed tail discernible in Fig. 3 is a secondary formation. It almost seems, then, as if Nature had repented of her own strange whim, for scarcely has she deprived the species of its tail when she replaces it with a new one! All three species, indeed, undergo striking alterations in shape during development. When first hatched, the length of the larva is considerably greater than its height; but the proportions are soon reversed, and the height then exceeds the length (Fig. 5, *a* and *b*). This state of things, however, is not maintained; at a length of barely 5–6 mm. the body of the oblong sun-fish (*Ranzania truncata*) is already longer than it is high (in the case of the Mola species this does not occur until a far greater length is reached), and from now onwards the height decreases in proportion to the length until the final adult stage is attained (compare Figs. 4, 5*b*, and 2, as well as Figs. 5, *c* and *a*, and 3).

At an early stage, so far back as the embryo in the egg, we find the first indications of that spinous equipment which is so characteristic a feature of the sun-fish larvæ and young. The same spines can be recognised in both genera, thus showing that these belong to the same type; otherwise, the development and size of the spines differ widely, affording in this very feature a means of distinguishing the three species with the greatest ease. In the case of *Ranzania truncata* the spinous equipment is comparatively modest; in *Mola lanceolata*, on the other hand, the spines attain such an enormous development that at a certain stage they exceed the length of the body. Five of the spines at this stage stand out from among the rest in point of size, so much so, indeed, as to deserve the name of horns. Three of these are unpaired and set in the same plane, directed forward, upward and down, the remaining two being paired and set in a plane at right angles to the first, and pointing obliquely to the rear (Figs. 5, *a*, and 6). In all early stages the two genera are easily distinguishable one from the other by the structure of the bases of the spines, which in Mola exhibit transverse ribs, these being lacking in Ranzania.

The Mola larvæ were invariably dead when found in the net; those of *Ranzania truncata*, on the other hand, I was now and then able to observe in a living state. The upper portion of the body (the entire part above the eyes) was dark, while the lower glittered like silver. When placed in a vessel full of sea-water, the larvæ could be seen shooting through the water at a surprising speed, propelled by the extremely rapid movements of the dorsal and anal fins, but apparently with no good steering qualities. Fig. 5, *a* and *b*, shows distinctly the two fins mentioned, which are set in a manner resembling that of the blades in a ship's propeller, here, however, always placed vertically.

The larvæ were found in the open sea, not far from the surface of the water: those of Mola somewhat deeper than those of Ranzania. They were very numerous in places, especially in the Sargasso Sea, and we have found between one and two hundred in the contents of a single net, where they are difficult enough to discern among the thousands of other small creatures. I cannot, however, go further into the question of distribution until we have been through the collections thoroughly, which is a matter of considerable time.

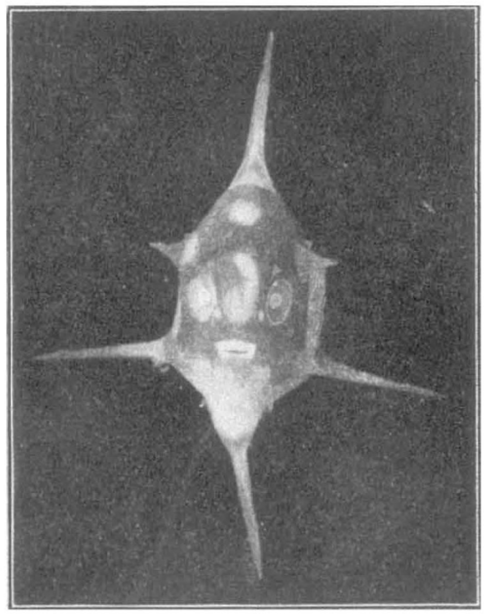

FIG. 6.—*Mola lanceolata*, post-larval stage. Length, 5 mm. Front view.

In the literature of the subject, tiny larvæ of the sun-fishes have, so far as I am aware, been mentioned and figured three times: First, by Sir John Richardson (1844–48)—this, strangely enough, only on account of a drawing made by the botanist, Sir J. D. Hooker, who caught the specimen in a tow-net in the South Atlantic; secondly, in 1898, by the Danes Steenstrup and Lütken, from material collected in the Atlantic by Danish sailing vessels many years ago; and, thirdly, by the Italian Sanzo, who in 1919 gave a figure of a specimen 2·8 mm. in length from the Straits of Messina. Richardson referred his—or rather Hooker's—specimen to the trunk-fishes, and termed it *Ostracion boops*; the other authors, however, realised that they were dealing with the young of sun-fishes, but were unable to make any closer determination of the species. Judging from the new material provided by the *Dana* expedition, I can now with full certainty state that all the specimens in question are larvæ of the oblong sun-fish (Ranzania). The tiny stages of the short sun-fishes (Mola), however, do not appear to have been figured or mentioned in literature up to now.

Electrons.[1]

By SIR WILLIAM BRAGG, K.B.E., F.R.S.

IN recent years the results of experimental research on the properties of electrons have accumulated with startling rapidity. As knowledge grows, the importance of the part played by the electron in the mechanics of the world becomes even clearer. There are all the right signs that progress is being made along a road that really leads somewhere; we are continually finding that, through some electron action, phenomena are linked together between which we had hitherto seen no connection. Precision is given to our views: we find ourselves able to express, quantitatively and with confidence, laws and relations which have been matters of vague surmise. Every experiment that is finished suggests others that are promising. The whole world of experimental physics is full of new life, and of the consciousness that after a period of hesitation the tide of discovery is sweeping on again. While knowledge grows by experiment, theory is also busy. The attempts to co-ordinate the new discoveries are of singular interest because of their daring, their width, and their strength: because they are so often fruitful in prediction: and, not least perhaps, because they seem so often to be irreconcilable with each other.

It helps to a right appreciation of the position as regards the electron if we observe its strong resemblance to the older state of things when first the atomic theory of matter was clearly defined. Just as chemistry has grown and prospered on its recognition of the unit of matter, so electrical science has already begun a new life, and, to all seeming, a most vigorous one, based on the understanding of Nature's unit of electricity. There are many different atoms of matter—nearly a hundred are distinguishable by their different chemical reactions; but the number of different kinds of electrical atoms is very much more limited. We have for some years been clear as to the existence of the electron, Nature's unit of negative electricity. More recently the work of Rutherford and Aston indicates that the nucleus of the hydrogen atom is to be regarded as the positive counterpart.

If the chemist has found so much profit in his recognition of the fact that Nature has just so many ways, and no more, of doing up parcels of matter, the electrician will surely gain in the same way when he grasps the fact that not merely is electricity measurable in quantity, but that there is already a unit of Nature's choice, possibly no more than one unit. We may say with justice that already the most wonderful advances in modern physics are the reward for our appreciation of this truth, and we may hope with equal justice that we are yet far from reaping the full benefit.

The first suggestion of the atomic character of electric charge came, it is well known, from observation of the laws of electrolysis. Since the movement of atoms or atom clusters or ions across the electrolytic cell was accompanied by a simultaneous transfer of electricity, in which each ion, of whatever nature, bore always the same charge or at least a simple multiple of it, there was a clear indication that this division of electricity into parcels of constant magnitude implied the existence of some natural unit charge. No progress, however, was or could be made so long as the charge could be observed only as an attachment to an ion: it was not even clear that it could ever have a separate existence. In the long series of researches which finally led to the isolation of the electron and the determination of its properties, there were certain that marked definite stages in the forward movement. Crookes examined the electric discharge in bulbs exhausted to a high degree by the new air pumps which he had succeeded in making; and he observed the so-called cathode rays streaming away from the negative electrode. He showed that they possessed the properties to be expected from a stream of particles projected across the bulb and carrying negative electricity with them; for on one hand they could heat up bodies on which they fell, and on the other they were deflected in crossing a magnetic field. Crookes spoke of a fourth state of matter and defended his view against the opposing hypothesis, held largely on the Continent, that the stream consisted of electromagnetic waves in some form or other. Hertz showed that the rays could pass through thin sheets of matter such as aluminium leaf, and Lenard took advantage of this to coax them outside the bulb and display their effects in the air outside.

In the later years of last century came the great experiments of Wiechert, Thomson, and many other well-known observers, who weighed the electron and measured its charge, and showed that there was only the one electron, though it was

[1] The Twelfth Kelvin Lecture delivered before the Institution of Electrical Engineers on January 13.