a scale never previously attained, and later was instrumental in establishing the origin of trench fever and its transmission by lice.

SYLVESTER MEDAL. Prof. Tullio Levi-Civita.—The investigations by Levi-Civita in pure geometry were the necessary foundations for the important physical discoveries of Einstein and Weyl. Levi-Civita has also shown himself one of the most fertile and original of investigators in differential geometry and theoretical mechanics.

HUGHES MEDAL. Dr. Francis William Aston.—Dr. Aston, by the use of an ingenious method of focussing positive rays, has shown that a large number of the elements are complexes consisting of two or more kinds of atoms, having identical chemical properties but differing in atomic weight by one or more units. Except in the single instance of hydrogen the atomic weight of each constituent is, to the limit of accuracy, a whole number on the basis of oxygen =16.

Live Specimens of Spirula.

By Dr. JOHS. SCHMIDT, Leader of the *Dana* Expeditions, Copenhagen.

FEW animals have been of more interest to zoologists than the little cuttle-fish Spirula. Related to the extinct Belemnites, and characterised by having an interior, chambered shell, it occupies an isolated position among recent species. Dead shells (see Fig. 2) are found on the sea-shores particularly of warmer seas, where they may drift ashore in great numbers, but the animal itself has hitherto ranked among the greatest zoological rarities, of which only very few museums possess a specimen.

FIG. 1.—Live specimen of Spirula, moving down toward the bottom of the aquarium. While so moving, the head is directed forward (downward), the fins at the rear are thrust out vertically, and the funnel is turned upward (this last is not visible here, the figure showing the specimen in dorsal view). About half natural size. Photo by K. Stephensen.

On the third *Dana* expedition we captured considerable numbers of Spirula in the North Atlantic, and were also fortunate enough to observe many specimens alive. I propose then, in the following, to describe some of our observations, throwing light upon the habits and occurrence of the species.

Appearance.—The following remarks apply to living specimens, a point which should be emphasised, as both colour and shape are often appreciably altered by preservation. The body, or mantle, is shaped like a cylinder cut away abruptly at the back, the head and arms protruding from the front part. As seen in Fig. 1, the arms are most often kept close together, as for example when the animal is in motion, giving the anterior part of the body a conical shape. At the hinder end are two fins, roughly semicircular. Their basal parts are not parallel, but converge toward the ventral side of the animal. The fins can be pointed straight out behind (Fig. 1), or laid flat in against the hinder part (Fig. 2). In the centre of the latter, between the two fins, there is a circular disc (the terminal disc) having in the middle a small bead-like organ. At the outer edge of the disc is a ring of pigment; otherwise it is colourless. The small central bead is a light organ.

The colour differs from that of other cuttle-fish. The mantle has a peculiar whitish sheen, most resembling that of asbestos. A further similarity to the mineral lies in the fact that the surface of the mantle is often somewhat frayed or fluffy. The greater part of the mantle is without pigment; some colour there is, however, of a rusty red, in a narrow band along the anterior margin of the mantle, especially on the dorsal side. There is also pigment on the hinder end of the body and at the base of the fins. On touching a live specimen, the rusty colour at the hinder end will often almost disappear, the chromatophores contracting to little dark specks. Arms and head exhibit the silvery sheen and also pigment, the latter dense and of a rusty brown. The extremities of the arms, however, especially of the two longer ones, are somewhat lighter and lacking pigment. The funnel also is pigmented, but not at its mouth.

Movements, etc.—The movement of the Spirula is characterised throughout by the presence of the interior, chambered shell, which is situate at the posterior end of the body, and tends to lift this portion in the water. A specimen recently dead, or a live one not inclined to active movement, will therefore, if placed in an aquarium with sea water, rise to the surface, and remain suspended there head downwards, with the lighter, posterior part uppermost. If moved from this position, it will immediately swing back to it again, like a weighted tumbling figure.

On board the *Dana* we frequently observed live specimens of Spirula. When taken from the net and placed in an aquarium, they would at first invariably remain suspended at the surface of the water, motionless, and to all appearance lifeless. As a rule, however, death was only simulated. Left to themselves, they would generally come to life, and soon begin breathing and other movements. The respiratory movements are effected by rhythmical contractions of the mantle, whereby water is forced out through the funnel. As the mouth of this is turned towards the rear—*i.e.* upwards—the water flows up along the ventral side of the mantle. This vertically ascending current of water is easily noticeable, from its disturbing the frayed surface of the mantle.

Like other cuttle-fish, Spirula often makes swift,

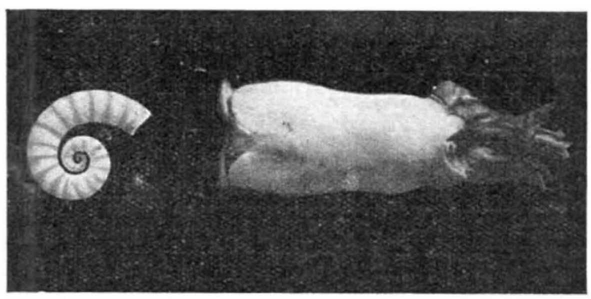

FIG. 2.—Preserved specimen of Spirula, about 39 mm. long (the head slightly damaged). The shell seen at the side, which has 35 chambers, shows the relative size of the shell in a specimen as illustrated. The animal is seen from the ventral side: the inner shell can be discerned showing through. About natural size. Photo by K. Stephensen.

jerky movements, dashing off suddenly in any direction: upwards, downwards, or from side to side. These rushes were generally made by "backing," *i.e.* the animal moved with its hinder end forward, having first "reversed" the funnel, so as to turn its opening forward towards the head, at the same time flattening the fins close in to the posterior end, approximately as shown in the preserved specimen, Fig. 2. Less frequently Spirula was observed in the aquarium making a forward rush with its head to the front—*i.e.* without reversing the funnel. It is possible, however, that this latter mode of progress is the usual one—for example, when in pursuit of prey.

In addition to these jerky movements, the animal also makes others at a slower rate. It may often be seen in the aquarium moving vertically downwards from the surface, head first. During the descent the fins are held vertical (see Fig. 1) and move with a rapid waving or fluttering motion which, in conjunction with the current of water from the funnel, now facing upwards (to the rear), carries the animal down towards the bottom. Sometimes it will come to a standstill in mid-water, at others it will not stop until it has reached the bottom, but so long as it remains below the surface the fins are kept in motion as described, and the funnel is pointed upwards. It may rise again slowly to the surface without altering its vertical position; the fins are then sometimes seen in motion, sometimes pressed in close to the hinder end.

In order to ascertain whether this movement of the fins was necessary to maintain the animal in the vertical position, which it adopted for the most part in our aquaria, we cut off one of the fins from a specimen, selecting a large and powerful individual for the purpose. It was at once evident that the lack of a fin in no way affected the maintenance of the vertical position; what did result was that the animal was now unable to keep under water. When placed at the bottom of the aquarium, it invariably rose again to the surface. On one occasion, when guiding it to the bottom, we happened to bring the creature into contact with the glass wall, when something new was seen. On touching the wall, it spread out its arms and clung to the glass, and was now able to keep under water. We tried to move it away from the glass by prodding it with the handle of a lancet. It relinquished its hold, but only to attach itself to the lancet handle in the same way. Evidently the eight short arms are highly sensitive to touch—the two longer less so, if at all. On this occasion also we had a sight of the animal's black, horny beak, and learned that it is capable of inflicting a powerful bite, as the handle of the lancet showed.

When left to itself the Spirula will remain suspended for hours at the surface, or lower down in the water, always in a vertical position, and with arms more or less closed in. When violently disturbed, the animal may occasionally discharge a small cloud of greyish ink. We managed to keep some specimens alive for more than two days in our small aquaria, with no aeration of the water. Generally, however, they lived only a little more than a day.

On several occasions we were able to perceive that the small bead-like organ at the posterior end is a light organ. It emits a pale, yellowish-green light, which, from the normal position of the animal in the water, is directed upward. In contrast to the light displayed by so many other marine organisms (crustacea, etc.), which flares up and fades away again, the Spirula's little lamp burns continuously. We have seen the light showing uninterruptedly for hours together.

Mode of Life.—The third *Dana* expedition has made captures of Spirula in 65 hauls from 44 stations, and in every case with implements used pelagically, without touching the bottom. The depths at which our specimens were taken varied from about 2-300 metres to about 2000. The greatest quantities were found at depths from 300 to 500 metres; none were taken in the upper 200 metres of the sea, though the nets were constantly drawn within this range.

Our investigations thus indicate that the species is bathypelagic, *i.e.* pelagic in deeper water layers, and so confirm the supposition advanced by J. Hjort (Murray and Hjort, "Depths of the Ocean," p. 595, London, 1910). A. Agassiz ("Three Cruises of the *Blake*," ii. p. 61, Boston and New York, 1888), who has examined a specimen of Spirula "dredged . . . from a depth of 950 fathoms," is of opinion that "from the condition of the chromatophores of the body, it evidently lives with its posterior extremity buried to a certain extent in the mud." This conclusion is doubtless erroneous. It would be unreasonable to suppose that the creature should thus bury its hinder part—which is lighter, owing to the shell, and also carries the light organ—in the bottom. It seems far more likely that the specimen brought up in the *Blake's* dredge was not taken from the bottom at all, but captured higher up in the water when hauling in.

Size, etc.—The 95 specimens of the third *Dana* expedition vary in length from 5 to 47 millimetres (maximal length of the mantle). On arranging the measurements graphically, they fall more or less evenly distributed along the millimetre scale, with nothing to suggest the presence of different "year-classes" in the material. Judging from this, it might seem as if the propagation of the species was not restricted to a short period of the year.

At one station (St. 1157, N. of Cape Verde Islands) we found the following:—

Depth (in metres).	Length of specimens (in millimetres).
250	9, 17, 20, 22
300	7, 17, 20, 21, 22, 27, 28
500	15, 41
1000	7, 15, 19, 22

At other stations, specimens more than 40 mm. long were found both in the deepest hauls and in those nearest the surface of all the hauls containing Spirula.

The species seems to attain maturity at a length of about 30 mm. (length of mantle). At this length the males begin to be hectocotylised, and the specimens more than 30 mm. which we opened were found to have mature sex organs (the females with large, oblong, honey-coloured ova, besides smaller eggs).

As previously mentioned, the Spirula has a chambered inner shell. As the animal grows the number of chambers increases, and a turn of the shell takes place. The figures below show how the number of chambers increases with growth of the animal.

Length of mantle (mm.).	Number of chambers in shell.
12	16
20	22
38	34 (mature male)
44	38 (mature female)

Approximately, then—but only approximately—an increase of one millimetre in length answers to the formation of one fresh chamber.

While the *Dana* was at the Virgin Islands in the West Indies (St. Thomas and St. Croix), as also at Bermuda, we often found considerable numbers of Spirula shells on the shore. Most of the shells were damaged, but so far as could be determined the intact specimens generally had between 30 and 40 chambers, *i.e.* representing, from the above, fully-grown mature specimens. From this I must conclude that at any rate the bulk of the shells found washed up on the coasts are those of fully-grown Spirula which have died of old age. When the animal is dead, and the soft parts rotting away, the shells, being lighter than water, will thus normally rise to the surface, and drift about with the surface currents, to be eventually washed ashore. *This bathypelagic species, then, becomes after death a surface form, its remains constituting a normal ingredient in the drift of the warmer seas.*

Fig. 2 serves to show the relative size of the shell as compared with that of the animal itself. The shell here illustrated has 35 chambers, and the length (of mantle) is 39 mm. Most of the undamaged shells we found on the shore were of this size.

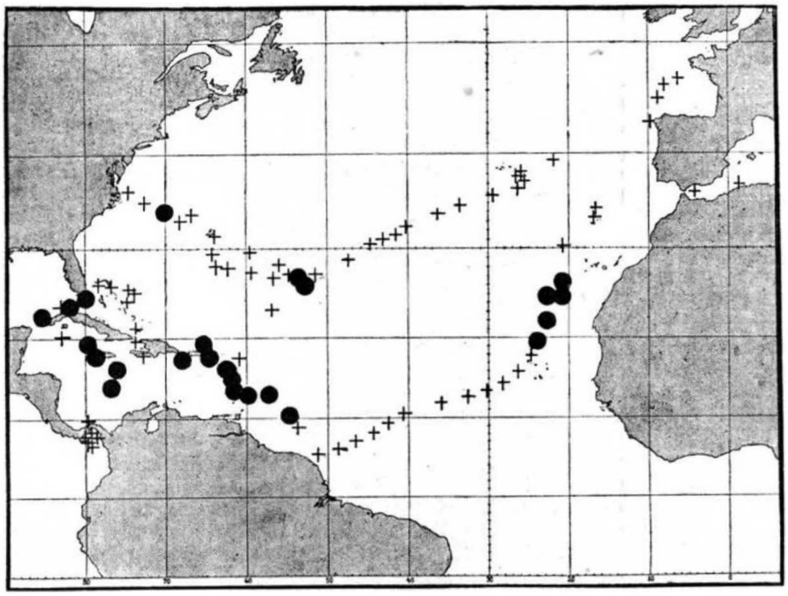

FIG. 3.—Chart showing occurrence of Spirula at stations of the *Dana* expedition. The black spots denote finds of live specimens, the crosses indicating stations where implements suited to its capture were used, but no specimens taken.

Distribution.—The first complete specimen of Spirula known to science was taken by the *Challenger* near the Banda Islands, west of New Guinea, and a few others were captured by subsequent expeditions (one by the *Blake* at Grenada, W.I., another by the *Valdivia* in the Indian Ocean, and seven by the *Michael Sars* in 1910 in the neighbourhood of the Canary Islands). The chart, Fig. 3, shows the localities where Spirula was taken by the present expedition. There were, as a matter of fact, more stations than are shown, but some lie so close together that it was impossible to indicate them on so small a chart. The stations where hauls were made which might have taken Spirula if present, but gave negative result, are marked by a cross. Our captures amounted to 95 specimens in all.

It will be seen that Spirula occurred between 10° and 35° N. Lat.: in the eastern part of the Atlantic from the Canary Islands to north of the Cape Verde Islands; in the Western Atlantic from Guiana and northward to the Virgin Islands and Puerto Rico, throughout the Caribbean; and also in the Gulf of Mexico and the Florida Straits, in the Sargasso Sea, and between Bermuda and the United States of America. From our previous investigations carried out with the *Thor*, we may conclude that the species is not found in the Mediterranean, or off the west coast of Europe from Spain to Iceland.

Solar Radiation at Helwan Observatory.

THE observations of solar radiation made at the Helwan Observatory in the years 1915 to 1921, which have recently been published,[1] lead to results of far-reaching importance.

With regard to the standardisation of instruments the position is satisfactory. The equipment of the Observatory includes two Ångström pyrheliometers made in Upsala as well as one made by the Cambridge Scientific Instrument Company, which was standardised by Prof. H. L. Callendar. There is also an Abbot silver-disc pyrheliometer. The observations indicate that if a correction of plus one per cent. is applied to determinations by the Upsala standard it comes into agreement with the Callendar and Abbot standards. A progressive deterioration in the Ångström instrument in daily use has been found, which is attributed to the deposit of dust on the blackened strips and a consequent reduction in absorbing power.

The usual practice at Helwan has been to take several observations in the course of a morning, with the sun at different heights, with the object of determining the "solar constant," the strength of the solar heat stream outside the earth's atmosphere. The usual assumption in reducing such observations is that the scattering and absorbing power of the atmosphere remains the same during the series of readings. The "solar constant" is arrived at by a process of extrapolation. In an earlier bulletin Mr. Knox-Shaw has directed attention to doubts as to the validity of this assumption, and has shown that if the air becomes less clear as the day progresses then a negative correlation between the computed "solar constant" and the computed transmission coefficient is to be expected.

It is now found that there is such correlation not only at Helwan, but also at other places for which observations have been published. The correlation coefficient averages about 0·6, and the value of the determinations of the solar constant by the extrapolation method is therefore much discredited. Further evidence of its unsuitability is furnished by the lack of correlation between the values of the solar constant found at different stations on the same day. It will be for the Smithsonian Institution to show that destructive criticism on the same lines will not affect the spectrobolometer observations on which the evidence for the day-to-day variations of the "solar constant" depends.

In the year 1919 Prof. Abbot developed a new method of observation based on the well-known fact that the more the sunlight is obstructed by dust, etc., the greater will be the glare surrounding the sun. The question has been investigated by the use of a "pyranometer" (fire-above-measure), as the instrument for determining the strength of radiation from

[1] Ministry of Public Works, Egypt: Helwan Observatory, Bull. No. 23. Observations of Solar Radiation, 1915–1921, by H. Knox-Shaw. Price 2 P.T.