this and other cases, based on the suggestion of Daly that igneous magmas are essentially basic at the outset. In a paper on "The Classification of the Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland" (Transactions of the Geol. Soc. of Glasgow, vol. xiii., p. 298), Mr. Tyrrell gives a useful account of the distribution of the various types. In cooperation with Mr. N. Martin, he describes the geology of the Auchineden district in the Kilpatrick Hills (*ibid.*, p. 322), and continues (p. 337) with an account of the igneous rocks of the vents and lava-flows. These prove to be olivine-basalts, though the sills were previously thought to be trachytic, on account of their fluidal structure and pale crusts. They belong to the late Palæozoic series. In a notice of rocks near Ballantrae (*ibid.*, p. 283), Mr. Tyrrell points to a granulitic diorite as a dolerite or gabbro metamorphosed by a later intrusion of serpentine. There is a pleasing sense of original outlook in these papers.

The Geological Survey of Ireland has issued a memoir by Messrs. Kilroe, Hallissy, and Seymour on the soils of the agricultural station at Ballyhaise (price 1*s.* 6*d.*), accompanied by a map showing types of soil and the underlying rocks, on the scale of eight inches to one mile. The methods adopted by this Survey for the examination of soils are fully stated. Another memoir, by Messrs. G. A. J. Cole and T. Crook (price 1*s.* 6*d.*), describes the submarine geology of the west coast of Ireland, so far as it can be known from the numerous rock-specimens dredged up by the official Fishery Survey. The amount of mingling of material by glacial drift-action appears to be very small on the west coast. Areas of Upper Cretaceous and Cainozoic limestone are indicated off the Kerry coast. As in the Ballyhaise memoir, a coloured map is included in the publication.

Prof. Cole describes (Proc. R. Irish Acad., vol. xxviii., sect. B, 1910, p. 113, price 6*d.*) the phenomena of weathering on the surface of a sheet of fine-grained diorite near Rathmullan, in Donegal, which is known as the "picture rock" or "scribed rock." The residual spheroids lie in box-like enclosures, the walls of which result from the toughening of the rock by the development of amphibole inward from its joint-planes.

In the *Irish Naturalist* for September, 1910, the Rosapenna area in northern Donegal is systematically described. Among the papers on its natural history is an excellent one on the geological structure, by Mr. J. de W. Hinch. G. A. J. C.

RUSSIAN MAGNETIC OBSERVATIONS.

UNDER the title "Die Variationen des Erdmagnetismus" Prof. Ernst Leyst has written a paper, occupying 250 pages and four plates, in the *Bulletin de la Société Impériale des Naturalistes de Moscou* for 1909. It deals with magnetic data from the Russian observatories at Pavlovsk (St. Petersburg), Irkutsk, and Katharinenburg, and with some corresponding data from Potsdam and Greenwich. The paper contains valuable statistical data for Pavlovsk, such as the secular changes of all the magnetic elements from 1873 to 1906, and diurnal inequalities derived from a 33-year period. Its main object, however, is to investigate the relations borne to terrestrial magnetism by sun-spot frequency and barometric pressure. A number of the data bearing on the sun-spot connection should be useful, such as diurnal inequalities in years of sun-spot maximum and minimum at the several stations. But their utility would have been greater if the numerical relationships between magnetic and solar phenomena had been gone into more critically. A good deal has been already done on these lines, even for some of the stations considered by Dr. Leyst, of which he seems unaware.

The parts of the memoir having a chief claim to novelty relate to the influence of sun-spot frequency on secular change and on the annual inequality, and to the relation between barometric pressure and the diurnal variations. Dr. Leyst finds secular change of declination to be more rapid near sun-spot maximum than near sun-spot minimum at all the stations included in his research except Katharinenburg. For the ratio borne by the rate of secular change at sun-spot maximum to that at sun-spot minimum he finds nearly 2 : 1 at Greenwich and more than 3 : 1 at Irkutsk. In the case of the annual inequality—*i.e.* the variation shown in the mean monthly values after elimination of the secular change—he concludes in pp. 206–7 that the range is increased at sun-spot maximum for declination and inclination, but diminished for total force. As regards barometric pressure, Dr. Leyst finds the range of the magnetic daily oscillations, both regular and irregular, at Pavlovsk to be larger on days of highest barometric pressure than on those of lowest pressure, the phenomenon being specially conspicuous near sun-spot maximum.

The author's zeal, as evidenced by the great amount of labour expended in his investigations, merits warm appreciation. One's confidence, however, in his conclusions would have been greater if the work had shown more distinct evidence of critical insight.

Lines of no secular change seem to traverse continents with continuous velocity. Their passage must occur at some stations in sun-spot maximum, and at others in sun-spot minimum, and must mark in either case a time when secular change numerically considered is a minimum. In short, secular change, while seldom varying rapidly with the geographical coordinates, is essentially a local phenomenon, whereas sun-spot frequency is not. The secular change results assigned by Dr. Leyst to Greenwich are certainly not fairly representative of sun-spot maximum and minimum there. They show not the least resemblance to some which the present writer has deduced for Kew from the longer period 1860–1909. If a difference of the kind supposed by Dr. Leyst does exist, it is in England, at least, of a comparatively trifling character. As to the annual inequality, that of declination—the element which ought to possess least uncertainty—presents the suspicious features that the ranges obtained have usually diminished as the number of years included was lengthened, while the types obtained at comparatively near stations have differed. In Dr. Leyst's case the results are derived from only two or three groups of three-year periods at either sun-spot maximum or sun-spot minimum, so that more than usual uncertainty attaches to the elimination of the secular change. Of all Dr. Leyst's conclusions, that as to the relations between the diurnal variations and the barometric pressure is undoubtedly the most remarkable. The figures which he gives for declination and horizontal force show during summer, not a small, but a large difference between the ranges of the diurnal inequality and the absolute ranges (absolute maximum less absolute minimum) on days of highest and on days of lowest barometer at Pavlovsk. In winter the phenomenon is much less apparent, which leads the author to regard the case as one of association and not of direct cause and effect.

If confirmed, the result, it need hardly be said, would be of great theoretical importance. A matured opinion on the question could be attained only by a minute study of observational data. Thus an independent investigation of data from some second observatory by a competent critic is to be desired. Several theoretical considerations naturally present themselves. Large absolute magnetic ranges are intimately associated with highly disturbed conditions, and such conditions are normally, at least, not local. High or low barometric pressure, on the other hand, is an essentially local phenomenon. A high at St. Petersburg means a low somewhere else, often even within the confines of Europe. If there is any such general association as Dr. Leyst supposes, a high barometer at Pavlovsk must be a symptom of a special set of conditions affecting an area much larger than that the barometric pressure of which is above the average. C. CHREE.

THE MICHAEL SARS NORTH ATLANTIC DEEP-SEA EXPEDITION, 1910.[1]

IN August, 1910, Sir John Murray offered to defray the expenses of an expedition to the North Atlantic with the Norwegian research steamer *Michael Sars*. The Norwegian Government, too, showed itself very indulgent towards the enterprise, and placed the vessel entirely at our disposition; and my colleagues, who have so long

[1] From a paper read before the Royal Geographical Society on January 16 by Dr. Johan Hjort.

taken part in these researches, Prof. H. H. Gran, Dr. Helland Hansen, Mr. E. Koefoed, and Captain Thor Iversen, all signified their utmost willingness to join the expedition.

On completing our preparations, we started off from Plymouth in the beginning of April, 1910, after being joined by Sir John Murray at that port.

During the four months that the cruise lasted, a great deal was accomplished. For oceanographic science it cannot but be interesting to learn that a little steamer, of only 226 tons, could carry out so many and such multifarious researches right across one of the mighty oceans, and I will accordingly give a few figures to illustrate what was done.

In the case of hydrographical material, we collected 2400 water-samples, more than 900 of which were from below the surface. At 110 stations we took 937 temperature observations from below the surface, while as many as 1625 observations of the surface temperature were recorded during the cruise. In addition, we obtained 258 measurements of currents and seven measurements of light. For the study of vegetable plankton we made 140 vertical hauls, and took 38 water-samples for filtering and 58 samples for examining with the centrifuge. For the larger plankton there were 95 vertical hauls with nets of different sizes, 193 horizontal hauls with silk nets, 80 horizontal hauls with pelagic trawls, and 18 hauls with a very large tow-net. Trawlings were undertaken on twenty-four occasions at different depths.

Our being able to carry out so many investigations, in spite of the fact that the ship traversed a distance of about 11,000 miles during the four months the cruise lasted, shows that oceanographic expeditions can be undertaken in small craft and for a relatively moderate expenditure; and this will most likely be a matter for consideration when future expeditions are planned.

Hydrographical Investigations.

At 110 stations we collected material for determining the temperature and salinity of the sea water. The temperature observations have now been corrected, the water-samples have been titrated, and the results are set down in vertical sections and charts showing the distribution of temperatures and salinities at the different depths. The distribution of temperatures and salinities in the sea between Newfoundland and Ireland in the month of July, 1910, can be shown in a diagram. Throughout nearly the whole section there is a layer with salinities of 35·5 per mille in the uppermost 150–200 metres. Both salinities and temperatures decrease in fairly regular proportion as we descend, until we reach a uniform layer termed "bottom water," in which the temperature is slightly below $2\frac{1}{2}°$ C., and the salinity is about 34·9 per mille. It is noteworthy that this salinity is exactly the same as has been found in the bottom water of the Norwegian sea during the previous investigations. During the cruise of the *Michael Sars* in the Atlantic, this same salinity has been discovered both between the Canary Islands and the Azores, and between the Azores and Newfoundland, and also outside the Bay of Biscay.

This uniform bottom water lies deeper in the eastern portion of the North Atlantic, off the south coast of Europe and the north coast of Africa, than in the western or north-western portion of the coast of America. East of Newfoundland it attains a comparatively high level. This would seem to indicate that the bottom water of the North Atlantic comes from the north-western portion of that ocean.

A chart shows clearly the influence of the Mediterranean; very salt and comparatively warm water streams out of the Mediterranean and sinks deeper down; outside Spain it mainly flows northwards, owing to the effect of the earth's rotation; another portion seems to follow the ordinary stream towards the south-west. Between the comparatively fresh cold water in the north-west and the relatively warm salt water outside Spain a belt extends from west of the Azores as far as the Faröes and Iceland, with fairly uniform salinities of 35 to 35·5 per mille, and temperatures of 6° to 8° C.

When we compare our temperatures with those of the *Challenger*, we find that they agree most satisfactorily, so far as the deep layers are concerned, and the temperature observations of the *Challenger* seem to have been very good. When we look at all the stations from the cruise of the *Challenger* in the summer of 1873, which are situated in the neighbourhood of the *Michael Sars'* stations of a summer thirty-seven years later, we find everywhere that the water in the mid-layers was much warmer in 1873 than in 1910. The differences of temperature go up to about 5° in the mid water-layers, but sink to 0·1° and 0·4°, respectively, in deep water. This seems to indicate that there are such very great fluctuations from year to year in the degree of warmth in these mid-layers that they even exceed the fluctuations in the seasons.

It is obvious that fluctuations of this kind in the degree of warmth of the Atlantic Ocean are most important, and need further investigation. In the Norwegian Sea such fluctuations in water flowing in from the Atlantic have been already previously investigated by the *Michael Sars*.

These determinations of the temperatures and salinities of salt water will subsequently be utilised for dynamic calculations. It will thus be possible to draw conclusions as to the movements of the different water-layers. These movements the expedition endeavoured also to investigate by means of direct-current measurements with the propeller current-meter which Ekman has constructed.

In the Strait of Gibraltar we tried first to anchor one of the lifeboats fore and aft, as had often been done previously in Norwegian waters. However, the strong current broke the lines repeatedly. We accordingly anchored the ship itself, with $1\frac{1}{2}$-inch steel wire and a warp anchor, in about 200 fathoms. The ship lay thus on April 30 from 2.30 a.m. until 5 p.m. During this time we took seventy measurements at eight different depths.

A comparison of diagrams representing the conditions at 9 a.m., when the inflow into the Mediterranean was at its height, and at 2 o'clock in the morning and 3 o'clock in the afternoon, shows that the effects of the tidal water are very great throughout the whole mass of water from the surface to the bottom. During the inflow, the velocity in the upper instreaming layer was about 1 metre per second, while in the lowest west-flowing layer it did not exceed one-third metre. During the outflow from the Mediterranean to the Atlantic there was hardly any surface current, whereas the outward current at depth had a velocity of up to 2 metres per second. The real velocities were actually greater, as the current generally ran in a slightly oblique direction to the axis of the strait.

During our experiments with the large otter trawl on the bank south of the Azores on June 12, our trawl stuck fast on the bottom. Instead of immediately getting it clear, this otherwise unfortunate circumstance was made use of for taking current measurements. The ship was thus anchored to the trawl at a depth of 668 fathoms (1235 metres). In all, we took ninety measurements at various depths down to 800 metres. On a diagram showing the current from hour to hour at a depth of 10 metres, the tidal movements can be distinctly seen. The actual main current ran southwards with a velocity of 8–9 cm. per second. Another diagram shows the currents in the different layers at three intervals of time:—(1) at 3.30 a.m.; (2) at 7 a.m.; (3) at 10.45 a.m. A comparison of the three figures shows that at all the depths down so far as 800 metres there were tidal movements. On the whole, the currents in the deeper layers flowed in a contrary direction to the movements in the upper ones. There was an astonishingly strong current at 800 metres at 3.30 a.m., but otherwise we found, as a rule, that the current was strongest close to the surface, while at 100 metres there was a tendency to a minimum, and a tendency to a maximum at 200 metres.

The measurements show, accordingly, that there can be very considerable tidal currents even down so low as 800 metres. The reason why they were so strong south of the Azores is probably to a great extent that the bottom there forms a large shoal, which the water presses up against.

Similar investigations with modern methods have never been undertaken before either in deep water or in the Strait of Gibraltar.

That there are tidal move entsmin the open sea and such strong currents, even at depths above 400 fathoms (800 metres), is interesting for many reasons, as it assists us in understanding the ocean currents, the tide-wave, the

distribution of living organisms, and the deposits along the bottom of the sea.

It has long been a puzzle to find that at great depths in the sea there are stones which are not covered by deposits, though they must undoubtedly have lain at the bottom for a long period of time. On the slopes of the coast banks south-west of Ireland, we shot our trawl in about 1000 fathoms (1797 metres), and found, *inter alia*, numbers of stones.

Sir John Murray has given them to Dr. Peach for examination. As mentioned in Sir John Murray's lecture to the Royal Geographical Society in Edinburgh on November 11, 1910, Dr. Peach "reports that fully 20 per cent. are glaciated fragments. They consist of granite, gneiss, shales, sandstones, chalks, limestones, and flints, and some of these contain fossil remains. The condition of these fragments shows that in many instances they projected above the surface of the deposit in which they were embedded. Dr. Peach has no doubt that these stones were carried by ice during the later phases of the Glacial period to the position in which they were found. They almost all belong to the series of sedimentary, metamorphosed, and erupted rocks now found *in situ* in this country and in Ireland. But the interesting question is, Why have these fragments not been completely covered up by the shells which are continually falling from the surface? Telegraph engineers give reasons for believing that in some localities and depths the rate of accumulation is at least 1 inch in ten years; at this rate all rock fragments deposited during the Glacial period should have been buried in the ooze far beyond the reach of the trawl. Most probably the tidal currents, which our observations showed to exist in deep water, extend right down to the bottom and remove the small Globigerina shells from any ridges. Still, there may be other explanations of the facts" (*Scottish Geographical Magazine*, December, 1910).

Phytoplankton.

The phytoplankton of the Atlantic Ocean, in so far as it can be collected with tow-nets, we know from Hensen's expedition in 1889, the results of which, by the way, have not yet been fully treated; further, from the extensive researches of Cleve. We have also received a valuable contribution from G. Murray and Whitting; the *Valdivia* expedition, carried out by the greater part of its investigations in the Antarctic and Indian Oceans, the researches in the Atlantic being comparatively few. Our knowledge regarding the distribution of species in the Atlantic is, notwithstanding, still very incomplete.

The samples taken by tow-nets in the open sea could not, any of them, compare in quantity with what can be obtained in the coastal waters in the Norwegian Sea. The only exceptions are the series taken to the west of Ireland and in the Bay of Biscay during April (stations 2, 3, 4, 7, 9, 10), where we met with large quantities of diatoms, even down to depths of more than 100 metres.

The oceanic samples are, however, very rich in species, there being, as a rule, at least fifty species in every single sample from the upper layers down to a depth of 100 metres. Many of the species are so sparsely represented that it has only been possible to find a few individuals, but the majority of them have, in spite of their scanty numbers, a wide distribution throughout the warm seas, and they have also been found in the Indian Ocean (*Valdivia*) and the Pacific (Kofoid). A few of them have not yet been described, though most of them are known from previous investigations. It will be a difficult matter to characterise the groups of species according to their geographical distribution within the area investigated; it can perhaps be done when our material has been fully treated, but certainly not as yet. All we can do at present is to distinguish the subtropical species from those which belong to temperate waters, and the oceanic species from the ones which have their centre of distribution along the coasts.

[The lecturer mentioned some instances of the occurrence of interesting forms belonging to the most important plankton-algæ, and then described more particularly the most important botanical discovery of the expedition, that by centrifuging the sea-water large numbers of very small algæ, mostly Coccolithophoridæ, were found. These go through the meshes of the tow-nets, and have therefore not been considered by previous expeditions which only used tow-nets, notwithstanding that Sir John Murray, during the *Challenger* expedition, had directed attention to their importance.]

To sum up, the chief results are as follows:—

(1) The quantity of plankton in the open Atlantic is far less abundant than what is found in coastal seas.

(2) At most of the stations where investigations took place, the maximum of plant-substance was found at about 50 metres' depth; it was, as a rule, scanty in the immediate neighbourhood of the surface, but appeared to be almost as abundant at 10 metres as at 50 metres. There was thus about the same quantity of plants all the way down from 10 metres to 50 metres.

At 75 metres the quantity was, as a rule, not more than half what we met with at 50 metres, and at 100 metres there was only about a tenth part.

This was the case with oceanic water. Where there was an admixture of coastal water, and an evident distinction between the surface layer at depth, the surface layer was comparatively richer in plants, and all the limits had an upward tendency.

(3) The different species are distributed, each in its own characteristic fashion, in regard to depth. The Peridinea keep comparatively near the surface, the diatoms prefer the deepest layers, while the Coccolithophoridæ affect an intermediate position.

(4) The number of living plant cells in the open Atlantic throughout the most densely populated water-layers (10–50 metres) varies, as a rule, between 3000 and 12,000 cells per litre sea water. Of these, about half are Coccolithophoridæ, the rest being Peridinea cells with a few naked flagellates and a sprinkling of diatoms.

THE LARGER ORGANISMS.

Deep-sea Fishes and Crustaceans.

Since the *Challenger* expedition laid the first foundation of our knowledge regarding the animal world of the deep sea, many succeeding expeditions have bountifully added to our store. As an instance, I may mention that we now know one thousand different species of deep-sea fishes, and that the German *Valdivia* expedition alone discovered no fewer than sixty-three new species.

Regarding these many species, however, only very little is known. In the case of quite a number of them we are acquainted merely with one, or at most a few specimens, while we are in almost complete ignorance as to their biology, their propagation, development history, growth, and outward conditions of life.

The view which generally prevails in literature nowadays is that the sea contains a motley abundance of forms either along its bottom or floating within its waters, subject to a uniformity of outward conditions of existence —that is to say, passing their lives in absolute darkness— and in a medium with constant temperatures and other physical surroundings.

To biologists, this view concerning the animal life of the deep sea has presented many difficulties. How is it that in a constant medium of the kind conceived there exist side by side so many distinct forms? And how, again, can animals with large eyes manage to live alongside blind forms? Why are some species furnished with numerous highly developed light-organs, while in the case of others these are entirely wanting? And how, too, comes it that within the same groups of animals, nay, often in closely affinitive species, the colours vary so remarkably, although the outer medium is the same?

These questions have become all the more pressing now that biological ocean research has discovered instances where in the same area of the sea there occur many different animal forms, each possessed of its own peculiarities in mode of life, habitat, and other respects, so that each species has its own characteristic area of distribution, even though it may occasionally be found together with its neighbours in the same catch. Our study of the spawning-grounds of the cod family (Gadidæ) in the North Sea and Norwegian Sea has shown us, for instance, that each of seventeen species has its particular spawning area, each species during the spawning period seeking out distinct characteristic depths, temperatures, and salinities,

so that, just as from a morphological point of view the species may be characterised by a definite form or structure, so, too, it is possible to characterise it by certain well-defined conditions of existence. These conditions characterise a given species quite as much as any morphological description, and, in fact, for a proper conception of the species both methods of investigation are supplementary.

Now, if we wish to investigate the conditions of existence under which animals live, we must naturally first of all ascertain where they live, which, in the sea, will be tantamount to discovering the depth where they reside. This alone can enlighten us regarding the conditions of light, the temperatures, and the salinities which are requisite for their existence.

Our knowledge regarding the haunts of the smaller organisms has advanced greatly in recent years owing to the fact that we have made use of small closing nets. But, with regard to the larger animals, especially fishes, we still possess little knowledge, despite the great exertions made in this direction, above all others, by the Prince of Monaco and the *Valdivia* expedition.

When fitting out the *Michael Sars* expedition, I kept ever in mind that one of the most important of all our aims should be to try and develop a method which would yield more information regarding the vertical distribution of deep-sea fishes.

The ideal instrument for capturing the larger pelagic organisms would be a big tow-net or pelagic trawl which could be sunk closed to the requisite depth, then opened and towed at a carefully ascertained depth, and finally closed again and hauled in. Such an instrument would be capable of capturing many of the larger animals, and it would secure them, too, at known depths. However, an instrument of this kind would naturally be extremely complicated, too much so, in fact, to prove trustworthy under our present system of working, and it would further entail a great expenditure of time. It would not be possible to operate many of these tow-nets simultaneously (amongst other reasons, because of the slip-leads), and consequently it would be necessary to undertake a series of hauls at the different depths.

This being the case, I gave up the idea of trying to construct any such instrument. A more practical plan seemed to be to try and tow a number of instruments simultaneously at different depths, and to compare the catches thus made with each other.

Thanks to a practical arrangement, we succeeded in towing ten different instruments from two wire lines. The arrangement generally adopted was as follows:—

At the surface	1 silk net of 1 metre diameter
,, 50 metres... ...	1 ,, ,, ,,
,, 100 ,, ...	1 ,, ,, ,,
,, 150 ,, ...	1 young-fish trawl
,, 300 ,, ...	1 silk net of ¾ metres diameter
,, 500 ,, ...	1 young-fish trawl
,, 750 ,, ...	1 silk net of ¾ metres diameter
,, 1000 ,, ...	1 young-fish trawl
,, 1250 ,, ...	1 silk net of ¾ metres diameter
,, 1500 ,, ...	1 large tow-net of 3 metres diameter (made of shrimp-net) or a young-fish trawl

With this, or a corresponding arrangement, we carried out some long hauls at about thirty stations, as well as from the Canary Islands to the Sargasso Sea, and from Newfoundland to Ireland. Some hauls were made in the daytime and others at night.

In this manner we collected a very large material, consisting of many kinds of pelagic organisms—fishes, cephalopods, crustaceans, medusæ, &c. I will here merely mention a few instances of the evidences our material affords as to the occurrence of these animals at different depths. To illustrate the method employed, I will begin with the remarkable and well-known Sternoptychid *Argyropelecus hemigymnus*. Of this species we caught 286 individuals at the different stations. The bulk occurred at depths between 150 and 500 metres; no individuals were caught above 150 metres, and only about 7 per cent. were taken at depths lower than 500 metres. If we assume, then, that these 7 per cent. were captured during the process of hauling in the appliances, and that none of them live at depths below 500 metres, we will have an idea of the accuracy of our method. By far the greater part were caught at a depth of 300 metres, where we generally had out a ¾-metre silk net, whereas at 150 metres and at 500 metres the appliance used was, as a rule, a young-fish trawl, that would have had a far greater capacity for catching these fish. It seems, accordingly, that the preponderating majority of the individuals of this species is very strictly limited to an "intermediary" layer, situated at a depth of about 300 metres. A closer investigation of the individuals captured at a depth of 150 metres shows that they were all caught at night. This may be due either to an upward nocturnal wandering or to chance, though on this question the smallness of our material makes it unsafe to hazard an opinion; in subsequent investigations, however, it will be worth while taking this fact into consideration. Among the individuals captured in 500-metres water there must, at any rate, be a few that were taken in the process of hauling in the young-fish trawl through the intermediary layer above; still, there were far fewer found in the young-fish trawl, which was towed in 1000-metres water—it seems evident that there must also have been some individuals swimming at the 500-metres depth.

This instance gives us a good illustration of our method, with its deficiencies and advantages. It is obvious that the greater the number of individuals we have to deal with, the greater is the probability of obtaining trustworthy information, and the safer are the conclusions we can deduce from our results. When, therefore, in what follows, I proceed to give some instances of the distribution in depth of different kinds of fish, I will begin by mentioning the commonest, or, at any rate, the most numerously captured forms belonging to the species *Cyclothone microdon* and *C. signata*.

Of these two species we caught altogether more than 7500 individuals, which were all measured and arranged according to their length and the instrument in which they were captured, so as also to obtain information regarding the occurrence of the different sizes at different depths.

C. microdon was found during the cruise of the *Michael Sars* in the northern Atlantic at every station where an appliance was towed in depth below 500 metres. Above 500 metres it was only met with occasionally. A table shows how, at a depth of 300 metres, we only came across one individual (in the southern section). In depths from 500 metres down to 1500 metres its quantitative occurrence appears to be fairly uniform.

In our northern as well as in our southern section we found approximately the same number of individuals in each of the three young-fish trawls, which we towed simultaneously, viz. at depths of 500 metres, 1000 metres, and 1500 metres.

When we next examine the size-distribution at the different depths, we see that it is perfectly clear that the smaller sizes are met with much higher up than the larger ones, which latter are mainly to be found at a depth of 1500 metres. In the northern section we find that at a depth of 500 metres the greatest number of individuals were 30 mm. in length, whereas at 1500 metres the majority were 60 mm. At a depth of 500 metres we only came across two that were more than 50 mm. in length.

The smaller and younger individuals, of a length of 20–30 mm., live, accordingly, to a preponderating extent, 1000 metres higher up in the water-layers than the majority of the largest and oldest individuals.

Another remarkable fact which strikes us when we study the table is that the average size of individuals is much smaller at the same depth in the southern than in the northern section.

C. signata resides in an intermediary layer, with maximum in the number of individuals at about 500 metres. In the case of this species, too, we note that the younger individuals are mainly to be found high up in the water (notice particularly the southern stations), and that the same size is to be found deeper in the southern section than in the northern.

We have a remarkable parallel to the areas of vertical distribution of these two fish species in the case of the red-prawn species. These latter unite with the black fishes in forming a populous and characteristic "com-

munity." We have come across no fewer than twenty-six species of prawns, of which we shall here refer to *Acanthephyra multispina* and *A. purpurea*.

A. multispina shared with Cyclothone the peculiarity of the largest and oldest individuals, being found in the nets towed at greatest depths, say at 1000–1500 metres. *A. purpurea* resembles *Cyclothone signata* in that its distribution is chiefly confined to an intermediary layer between 500 metres and 750 metres in depth.

The instances I have given show the utility and exactness of our method of working. Where we have to deal with catches of great numbers of individuals, our errors and inaccuracies will undoubtedly be very small. The catches which the *Michael Sars* made of such forms as Cyclothone and Acanthephyra were certainly most satisfactory in this respect. But when we come to the catches which the expedition made of scarce forms, or forms more difficult to capture, then we are bound to own that the method of working even of the *Michael Sars* is not sufficiently effective. Still, it is interesting to examine a few of the results yielded by the method we employed with the object of discovering some conformity, or some general rule, for the peculiar distribution of the different organisms at different depths.

I will commence with the view I formed during the cruise itself from the appearance of the catches on board, which view I find has also, to a certain extent, forced itself upon other observers, chief amongst whom I may mention Prof. A. Brauer, to whom was confided the treatment of the fishes of the *Valdivia* expedition. I found on examining the catches from great depths that the black and dark-red forms were the all prevailing ones among animals from the greatest depths.

Black-coloured pelagic fishes are few in number, though they might be termed numerous if we take into account what was previously known concerning "scarce" forms. *Gastrostomus bairdii*, Cyemaatrum, and *Gonostoma grande* were only caught at depths from 750 metres downwards. The two species *Gonostoma elongatum* and *Ptotostomias guernei* were caught at great as well as small depths, even in some cases so high up as 150 metres below the surface. The rule, then, that the black forms are only to be found at great depths, cannot be said to hold good universally.

The question accordingly arises whether among the black forms there may not be said to be groups or different types. In common with several previous observers, I have been struck by the fact that even the anatomical structure of the black fishes points to different modes of living. When we compare, for instance, pictures of the above-mentioned five species of fish, we see that, of the three species which were only found at great depths, *Gastrostomus bairdii* and Cyemaatrum are quite without light organs, and *Gonostroma grande* has but small ones, as is also the case with *Cythotlone microdon*. In *Gonostoma elongatum* and *Ptotostomias guernei*, the light organs are much more developed (as is also the case with *Cyclothone signata*). It is an interesting fact now to notice that every single individual of these two species which was captured higher up than 500 metres was caught at night, which coincides with previous observations regarding black forms, such as Idiacanthus and Astronesthes, which have been caught at night right close up to the surface. We may assume, accordingly, that among the black deep-sea fishes there are several different modes of life, that is to say, several different "biological types."

With the view of a better understanding of the occurrence of these black and red types in the sea, I have endeavoured to compare their vertical distribution with the intensity of the sunlight in different depths and at different parts of the ocean.

We have seen that the upper limit for *Cyclothone microdon* and the red crustaceans in the northern section from Newfoundland to Ireland, or about 50° N. lat., was approximately 500 metres below the surface, and we have also noticed that the limit of depth for the same forms at the southernmost stations, or about 33° N. lat., was some 200–300 metres deeper. In the Norwegian Sea I have already previously investigated the intermediary pelagic fauna, and found pelagic red prawns as well as the dark-red fish *Sebastes norvegicus* at depths of about 200 metres below the surface. Sebastes was taken, for instance, with floating long lines in considerable quantities on a course Jan Mayen-Lofoten—that is to say, in about 67° N. lat., at a depth of 200 metres—and it was even found, though in decreasing quantities, higher up. Along the Norwegian coast, in the fjords and sounds, we have a particularly rich fauna of red crustaceans (especially *Pandalus borealis*) residing at depths the maximum of which in the north, at any rate, may be put at about 200 metres. Now, if we calculate the depth to which the rays of the sun penetrate, after passing through the same distance in the water, assuming always that the rays are direct, and that the rate of absorption is the same, we find that the rays will have passed through the same distance to reach a depth of 500 metres in 50° N. lat., that they will pass through to reach 650 metres in 33° N. lat., or 300 metres in 67° N. lat.

However, the transparency of the water varies greatly in different regions. If we take the results of previous observations during different expeditions, we may set down the visible depth in the open sea as being, roughly, 50 metres in 33° N. lat., 40 metres in 50° N. lat., and 25 metres at the outside in the Norwegian Sea in 67° N. lat. Taking this into consideration, we find that there will be the same intensity from the retilinear rays

In 33° N. lat.,	at about	800	metres'	depth	
,, 50°	,,	,,	500	,,	,,
,, 67°	,,	,,	200	,,	,,

The red and black animal forms, as has been found in the investigations I have just described, have an upper limit in the different waters which corresponds everywhere with the same intensity of light.

During the Atlantic cruise of the *Michael Sars* we undertook a series of measurements of the intensity of light with a photometer constructed by Dr. Helland-Hansen; to determine the intensity of the different colour rays, Dr. Helland-Hansen made use of panchromatic plates and gelatin colour-filters. The observation south and west of the Azores (that is to say, at the southern stations) showed that the rays of light strongly affected the plate at a depth of 100 metres. The red rays were weakest here, while the blue and ultra-violet rays were strongest. At a depth of 500 metres the blue and ultra-violet rays were still distinctly visible, and at a depth of 1000 metres the ultra-violet rays were yet perceptible. In 1700 metres, however, there was not the faintest trace of light, even after the plates had been exposed for two hours in broad daylight.

In the above-mentioned deep, which denotes the upper limit for the black and red forms during the daytime, we may after this, no doubt, assume that there are only to be found chemically effective rays from the violet portion of the spectrum. Now, seeing that the coefficient of absorption for the red rays, as compared with the violet, is about in the proportion of 30 to 1, and that our observations failed to trace any red rays at a depth of 500 metres, it follows that the red animals at this depth must be quite as invisible as the black ones. It is interesting to note, in this connection, that it is only at night that the black fish with large light organs are found high up in the water, and that red crustaceans in the Arctic regions, as was noticed by Scoresby in the case of *Hymerodora glacialis*, are to be found right up to the edge of the ice at the surface of the sea.

Above the region I have hitherto been describing, with its black and red forms, our parallel hauls have shown us an equally characteristic, though very different, group of pelagic fishes. Their peculiarity is that their body is always more or less compressed from one side to the other. In colour they are dark along the back and silvery or shining, with a bluish-violet gleam along the sides, their eyes are large and often telescopic, and most characteristic of all, I suppose, are their strongly developed light organs; characteristic forms are especially to be met with among the families Sternoptychidæ and Stomiatidæ. From a table showing the depth at which a number of these forms occur, it can be seen that 500 metres may be taken as their lower limit, and that the greatest number of individuals reside at a depth of 300 metres; above 150 metres there were only a few found, and even those that

were met with in 150 metres, or higher up, were with very few exceptions taken at night.

Cyclothone signata may be said to approximate to this group so far as distribution is concerned, and this form also has large, well-developed light organs. A closer analysis of the occurrence of these forms in different latitudes would probably reveal much of interest, though this must be reserved for subsequent investigations.

It is important to lay stress upon the fact that these shining colours, remarkable light organs, and peculiar telescopic eyes do not belong to the dark region in the sea where the sunlight never penetrates, but, on the contrary, to a region where there are, at any rate, large quantities of the rays which are nearest to the blue, violet, and ultra-violet portion of the spectrum.

There has been a good deal of disputing as to whether the light emitted by the light organs was entirely produced by the vital energy of the organisms, or whether the organisms had the power of transforming the ultra-violet rays of the sunlight into rays of lesser wave-length. The observations I have described here cannot, of course, decide questions of this kind, but they show, at any rate, that the light-emitting organisms live in a medium in which there are quantities of rays from the sunlight; and we recognise, further, in these forms a new biological type of organisms, a separate group with quite characteristic outward conditions of existence.

The higher we ascend towards the surface of the sea, the more varied become the forms and colours of the organisms, and the more diversified become also, probably, their conditions of life. I have up to now only been able to examine a portion of the large material from the uppermost water-layers, and will merely mention a single group from this region, namely, the larvæ and young fish forms. Of these we have collected a very large quantity, amounting to thousands. It has been impossible to determine them all, as this will be a long and laborious task.

A table shows how, out of 3600 transparent large and young fishes, 90 per cent. were secured in the appliances operated from the surface down to a depth of 150 metres. These forms are young stages of many different kinds of fishes.

A very interesting and important question is the quantity of animals in the different depths. This question has not been much studied yet. I believe myself that the upper limit of the red and dark-coloured forms is particularly rich. In the Norwegian Sea I found that the occurrences of a rich intermediate pelagic life corresponded to a great rise in the density of the sea water, and I explained this thus, that the food of the animals, sinking down from the upper layers, might accumulate there. The closer study of our material may give more information about this interesting question.

In my preceding remarks I have given a number of instances of the observations we were able to make regarding the depth distribution of fishes when we examine material collected by means of parallel hauls. But it is obvious, too, that this material can equally well be used for ascertaining their horizontal or geographical distribution, and it is only after studying simultaneously as well their vertical and horizontal distribution that we can characterise the outward conditions under which they live. If we look at the horizontal distribution as found by the *Michael Sars* and compare it with previous observations in the northern Atlantic, we shall get some idea of how little knowledge we possess concerning the most ordinary forms inhabiting the ocean between Europe and the coast of the United States. I will base my comparison entirely on Brauer's valuable summary of what was previously known, and on the same instances that I have employed when discussing the vertical distribution.

Black fishes and red crustaceans were caught at all the stations during the cruise of the *Michael Sars* in the Atlantic wherever we lowered our appliances to a depth of 500 metres.

Transparent young fish were captured over the whole area of investigations, though in very varying quantities.

In the open sea over the greatest depths, the Scopelidæ are undoubtedly the most numerous group among the young fish. We find also many extremely interesting forms with stalk eyes, telescope eyes, and so on. Amongst those with telescope eyes there are many of a perfectly transparent new form, which may in all probability be assigned to the genus Dysomma. They were mostly caught in the uppermost 150 metres.

When we have succeeded in determining these young stages, we will be able to throw much light upon the life-history of many important species of fish. The numerous forms of the group Leptocephalidæ will by no means be the least interesting among them. The 195 individuals that were found are believed to belong to no fewer than twenty species, of which a good many are entirely new.

I have previously (in NATURE of October 24, 1910) published a short description of a number of these Leptocephalidæ, which we were able to prove to be the larvæ of the European eel. These larvæ (forty-four specimens in all) have this much of interest in them as compared with previous finds, that they were met with right out in the Atlantic Ocean, far away from the slopes where they previously had been discovered.

Trawlings.

To operate the big trawl at the greatest depths of the North Atlantic, about 2500 or 3000 fathoms, proved a very difficult task. However, two of our hauls were quite successful. The first was in the Bay of Biscay, at a depth of 2500 fathoms. Our catch contained a number of invertebrates, including holothurians of the genus *Elpidia alcyondae*, sponges, and ascidians, and two fishes belonging to the genus Macrurus.

The second haul, between the Canary Islands and the Azores, at a depth of 3000 fathoms, yielded only a very few living organisms. In the half-barrel of mud brought up by the trawl we found thirty pumice-stones overgrown with Stephanocylis and Limopsis, and there were also two holothurians (*Laetmogone violacea* and Elpidia, sp.), sertulariæ, fragments of an umbellularia, an antipathes, a spike of a cidaris, fragments of shell of argonauta, as well as one Bulla tympanica of a whale, and two shark's teeth, of which the first belonged to a carcharodon and the second to an exyrhina. Of fishes there were one Malacosteus, one Alepocephalus, one Leptocephalus, one Argyropelecus, and a form not yet determined. All these I believe to have been pelagic, and to have been taken during the process of hauling in. Regarding one form alone, there was doubt whether to class it as a bottom fish or as pelagic, namely, an unquestionably new species much resembling *Ipnops murrayi*.

Judging from the appearance of the trawl when being lowered and when being afterwards hauled in, I consider this haul to have been, technically speaking, a success, and I cannot explain the catch otherwise than by supposing that at those profound depths there was an absolute poverty of animal life. It remains a question whether all these great ocean floors are equally barren in regard to animals, and especially fishes. So far as I know, the literature on the subject only records the capture of a few Macruridæ from the greatest ocean deeps, this being all the evidence that there is to favour belief in the occurrence of larger fish there. But is it perfectly certain that even those are not also pelagic? On several occasions during the cruise our tow-nets captured over the greatest ocean depths pelagic specimens of Alepocephalus, which is generally brought up by the trawl. In any case, the animal life there must be extremely scanty; and this is borne out by the vertical hauls with our big net below 1500 metres, which I have referred to when discussing *Cyclothone microdon*.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The professor of mineralogy has, with the consent of the Vice-Chancellor, reappointed Mr. A. Hutchinson to be demonstrator in mineralogy and assistant curator for five years from January 1.

Dr. Hobson has been appointed chairman of the moderators and examiners for the Mathematical Tripos, Part ii., 1911.

Mr. C. E. Inglis has been appointed chairman of the examiners for the Mechanical Sciences Tripos, 1911.