Baron von Richthofen (one of a series on Eminent Geographers)' besides several other papers, and notes on political geography and statistics. The *Rundschau* is edited by Prof. Umlauft, and published by Hartleben of Vienna.

THE steamer *Louise* returned to Hammerfest on October 1 from the southern part of the Sea of Kara. The Captain reports that, owing to the prevalence of a hard frost and the consequent accumulation of ice, vessels are unable to pass. The *Louise* left the Danish exploring vessels, *Varna* and *Djimpha*, on September 22, ice-bound, at a point eighty miles to the east of the island of Waigatz. All was well on board, and hopes were entertained that they would shortly be set free.

IN the October number of the *Proceedings* of the Royal Geographical Society, the leading papers are on the Cameroons District, West Africa, by Mr. George Grenfeld; and on the Coast Lands and some Rivers and Ports of Mozambique, by Mr. H. E. O'Neill, H.B.M. Consul, Mozambique. From the Notes we learn that Mr. H. Whiteley, who has devoted himself for many years to natural history pursuits in the interior of British Guiana, has just returned to England. He resided for upwards of a year among the Indians in the neighbourhood of the famous Mount Roraima, of which in its many aspects he made a numerous series of drawings. The number, we may say, contains a full report of the important paper on the Deserts of Africa and Asia, read by M. Tchihatcheff at the Southampton meeting of the British Association.

PELAGIC LIFE[1]

AS used technically by naturalists, the term "Pelagic" applied to living things denotes those animals and plants which inhabit the surface waters of the seas and oceans. Just as the land surfaces, the sea shores, and the deep ocean beds are each tenanted by assemblages of organisms specially adapted to the conditions of existence there occurring, so the surface waters of the oceans are inhabited by a characteristic fauna and flora. The special modifications in structure which the members composing this fauna and flora exhibit as adapting them to their peculiar environment are of a most interesting and remarkable character: and it is concerning the nature of the Pelagic fauna and flora, the mutual relations between the two, the strange forms which Pelagic animals assume, their curious habits of life, their zoological and geological importance, that the present lecture on Pelagic Life will consist. I have spoken of pelagic life as belonging to the surface waters of the oceans because it is in the superficial strata in which it appears to be most fully developed; but, as we shall see in the sequel, it is impossible as yet to limit definitely the range of pelagic forms in depth, and we shall even have to refer to some connections of the fauna of the deep ocean bottom with that of the surface.

Pelagic life then includes the inhabitants of the whole ocean waters, excluding those belonging to the bottom and shores; that is to say, the inhabitants of an area equal to nearly three-quarters of the surface of the globe. And it may tend to enhance our appreciation at the outset of the importance of the pelagic fauna if we reflect that in point of numbers pelagic animals probably far exceed all others existing. The extraordinary abundance of life, as seen at the surface of the ocean under certain circumstances, when the water is often discoloured for miles and its surface strata absolutely filled with small animals, has often been described by voyagers, but can never be fully realised till it is actually witnessed.

The existence of pelagic animals at all is directly dependent on that of pelagic plants. No animal life can exist without vegetable food as a basis, and the first living substance which came into existence must have been capable of constructing protein for itself from inorganic sources, and been physiologically a plant. Now, in many regions the sea-surface teems with vegetable life. In the Polar waters diatoms swarm, sometimes occurring so abundantly that they render the water thick like soup, and being washed up on the ice in the Antarctic regions, colour it brown, as Sir Joseph Hooker showed. When a fine net is towed overboard amongst them, they fill it with a jelly-like mass that, when squeezed in the hand, leaves behind their skeletons, a mass of fine silica like cotton wool. In the temperate and warmer seas, diatoms, though still present, are scarcer, and their place is taken by other simple minute algæ, mainly Oscillatoriæ. As we passed through the Arafura Sea between Australia and New Guinea in the *Challenger* Expedition, the whole sea for several days' voyage was discoloured far and wide by such algæ, and smelt like a reedy pond; and in the Atlantic we passed for days through water full of minute algæ (*Trichodemium*) gleaming in the water like particles of mica. From these fine algæ the simpler animals, on which the higher animal forms subsist, derive their food. No doubt the food-supply is largely supplemented by organic *débris* of all kinds drifted from shores, and by floating sea-weeds, certain species of which, like the gulf-weed, grow in a pelagic condition. Coccospheres and Rhabdospheres may very possibly be of vegetable nature, and contribute to the pelagic stock of food, together perhaps with some of the Cilio-flagellata, such as Ceratium,[1] which may prove also to be physiologically vegetable. However, in many parts of the ocean vegetable organisms are not markedly abundant, and it had always seemed to me that the ultimately pelagic food supply was scarcely as abundant as it should be to account for the vast extent of pelagic fauna, until the recent establishment by Dr. Karl Brandt, of the existence of the curious condition of mutual relations of certain animals and plants known as symbiosis.

It is found that amongst the tissues of certain animals there are constantly imbedded quantities of unicellular algæ. These algæ are not to be regarded as parasites, but a relation of mutual benefit exists between them and the animal with which they are associated; they are nourished by the waste products of the animal, whilst the animal thrives on the compounds elaborated by them and the oxygen they set free. Such an association of mutual benefit is termed symbiosis, and it was in the case of some of the most abundant of pelagic animals, the Radiolarians, that the true nature of the algæ in question was first discovered by Cienkowsky. I shall throw on the screen a figure of one of these Radiolarians Collozoum inerme. It consists of a rounded mass of jelly traversed by fine radiating pseudopodia with a central spherical sac or capsule, and in the interior of that a large oil globule. One function of the oil globule apparently is to float the animal at the water's surface. The animal has the power by some means of rising or sinking at will, probably by means of a modification in the size of the oil globule. Embedded in the jelly outside the capsule are seen conspicuous bright yellow cells, one of which is shown in the act of dividing. These cells contain starch, and are the unicellular algæ, which Brandt has termed Zooxanthellæ. It is obvious that a compound organism such as this is self-supporting, requiring no external source of organic food; and it would be quite possible to conceive the existence of a vast pelagic fauna having Radiolarians combined with their Zooxanthellæ only as a basis. The single organism here represented on the screen is not larger than a pin's head. In the living condition thousands of such are united, clustered together to form little bolsters of jelly about half an inch long, and on calm days on the ocean the whole surface water may be seen full of such masses for miles and miles, as far as the eye can reach, forming a vast supply of self-supporting food for other pelagic organisms. It is probable that the symbiotic condition in Radiolarians is of great importance in the general economy of pelagic life. There are other pelagic animals, for example, Ctenophora, in some of which unicellular algæ are similarly present. Symbiosis may possibly have been more common amongst pelagic faunas of earlier geological epochs, when diatoms apparently were not abundant or non-existent. The Radiolarians are characteristic members of the pelagic fauna. Most of them are provided with most beautiful siliceous skeletons, as, for example, *Rhizospæra leptomita*, now on the screen. It is, as may be seen, provided with a stock of Zooxanthella like Collozoum.

Animals are pelagic in very various degrees, and may be placed under a series of categories accordingly. There are the pelagic animals *par excellence*, those that are found at the greatest distances from shores, and which are capable of passing their whole existence there, and are floated only accidentally to land. Such are the Radiolarians, Siphonophora, very numerous Crustacea, Alciopa, Tomopteris, Heteropods, Ianthina, Pteropods, the Pelagic Cephalopods, Salpæ, and Pyrosoma, and numerous pelagic fish. These might conveniently be termed eupelagic. Then there are others, such as many Scyphomedusæ and most Ctenophora, which, though thoroughly pelagic in habit, are met with in greatest

[1] Address at the Southampton meeting of the British Association, August 28, by H. N. Moseley, F.R.S., Professor of Human and Comparative Anatomy, Oxford.

[1] Mr. John Murray has observed that species of pelagic ceratium are to be met with, often forming long chains, composed of individuals united in linear series. I observed an instance of the same fact myself. It seems to give some additional indication of the possibly vegetable nature of certain of the Cilio-flagellata.

numbers near land. There are further numerous animals which are pelagic only in their larval condition, and which, swarming at the surface with the strictly pelagic forms during their early stages, sink to the bottom when mature to lead an entirely different existence. With other pelagic forms, the converse is the case: the pelagic snakes, turtles, and birds come on shore to rear their young, spending most of their adult life on the ocean, and certain whales approach the shore at the breeding season. These two last groups may be termed hemipelagic.

It is impossible to draw a sharp line between any of these groups; they run into one another indefinitely. Thus, unlike the abundant flying-fishes (Exocœtus), the flying gurnets (Dactylopterus), are never found very far from land, but lead a partly pelagic existence, taking frequent flights from the surface, and partly inhabit the bottom in shallow water, being taken sometimes at the bottom with a hook and line. Amongst the Hydromedusæ and Scyphomedusæ, all gradations of pelagic habit occur. Many of both are attached at the sea bottom at certain stages in their life history, or rest on it habitually, some possibly in very deep water; others, closely allied, exhibit no fixed condition, and are entirely pelagic.

The Sargasso Sea has a peculiar fauna of its own, which cannot be considered as strictly pelagic, composed of animals specially adapted to cling to the gulf-weed and inhabit it, and differing in general aspect from other pelagic forms. Very much has been written on this fauna, which is so special that it may well be left out of consideration here.

Most characteristic of pelagic animals is the almost universal crystalline transparency of their bodies. So perfect is this transparency that very many of them are rendered almost entirely invisible when floating in the water, whilst some, even when caught and held up to the light in a glass globe, are scarcely to be seen. The skin, nerves, muscles, and other organs, are absolutely hyaline and transparent in these forms, but natural selection seems to have been unable to render colourless the liver and digestive tract in many instances. So these parts remain opaque, of a yellow or brown colour, and exactly resemble, when seen in the water, small pieces of floating sea-weed. A familiar example is Salpa, Pelagonemertes is another.

Certain few pelagic animals are coloured bright blue for protection, so as exactly to resemble the colours of the waves. Such are Minyas cœruleus, Velella, Porpita, Physalia, Glaucus, Ianthina, all of which are forms which float at the very surface, with part of their bodies more or less out of the water. The blue coloration seems to be connected with this latter circumstance, as protecting the animals probably from predatory pelagic birds, to which they would be invisible at any distance. Velella does not, however, thereby escape its enemies altogether, for a young turtle which we caught at sea during the *Challenger* expedition, had its stomach full of Velellas, and we often found them in the stomachs of albatrosses. Ianthina, the well-known bright blue gastropod, constructs a float built in compartments, which is attached to its foot. If this float be detached, the animal sinks and dies. It is said to be devoid of eyes. Glaucus is a nudibranch mollusc, which has the sides of its body modified into curious fin-like fringed lappets. It floats habitually with its ventral surface upwards, its foot being applied to the surface of the water, just as is that of the common pond snail, Paludina, when the animal is creeping at the surface of the water. In consequence of the position thus assumed by Glaucus, its ventral surface is coloured deep blue, whilst its dorsal or under surface is of a glistening lustrous white. One is so accustomed to animals floating with their back upwards, and being coloured accordingly dark on the back and light underneath, that the appearance of the animal is most deceptive, and, indeed, entirely misled Dr. Bennett, who, in his account of the habits of the animal, speaks of the blue aspect of its body as its back throughout. The curious fish, the Remora,[1] which adheres to sharks and ships, is similarly dark on the exposed ventral surface, and light on the back, and one can hardly persuade oneself of the fact when one looks at one in the fresh condition. The circumstance proves how completely the arrangement of such colouring is protective in object.

Glaucus is most persistent in maintaining its position with its back turned downwards. I turned one over several times. It struggled with its fins somewhat like a turtle on its back, and quickly regained its position. Curiously enough, according to Dr. Bennett, it feeds on Velella, which, like itself, is blue. Similarly the blue Ianthina feeds on the blue Velella.

[1] This fact seems not to be recorded by icthyologists nor figured. When the fish is put in spirits the light tint of the dorsal surface disappears.

Some few pelagic animals are most brilliantly coloured, and one small Copepod Sapphirrhina has always excited the admiration of naturalists, being unsurpassed by the brilliant metallic lustre of the humming birds, and displaying all the colours of the spectrum with an intensity like the gleam of the diamond. The figure of this animal now on the screen appears brilliant enough, but it gives but a faint idea of the actual brilliancy of the animal. The colouring in this case is of sexual import, being confined to the males.

A further remarkable fact about pelagic animals is that very many of them have either no eyes or very large eyes, the latter condition being most common. Thus the whole of the Pteropods have either no eyes or mere rudiments of them, and the Siphonophora and Ctenophora have no eyes.

On the other hand, animals with huge eyes in proportion to their size are common in the pelagic fauna. As an example, I shall throw on the screen a representation of the remarkable pelagic Amphipod *Phronima sedentaria*, you observe the enormous size of the compound eyes, which occupy the entire front of the animal's body. The female *Phronima sedentaria* has the curious habit of living in a tub-shaped transparent house, open at both ends, which it forms by gnawing out the inside of a young Pyrosoma colony, and, with its brood of young clustered round it inside, it sculls its tub with great rapidity through the water.

Here you see another crustacean, a Copepod of the genus Corycæus. All the species of Corycæus have a very large pair of eyes; but in the present form the eye apparatus is so extraordinarily enlarged that a large horn-like outgrowth of the body has been formed projecting from under the thorax, in order to accommodate the nervous structures and get a long enough focus for the lenses. This figure is from an unpublished drawing by my lamented colleague on board the *Challenger*, Rudolph von Willemoes Suhm, who specially devoted himself to the investigation of pelagic animals during the *Challenger* voyage. He names in MS. this curious form, which is apparently as yet undescribed Corycæus Megalops. The animal is of a fine blue tint when living. Most remarkable of all for their eyes are, however, perhaps the pelagic annelids, the Alciopidæ. Their eyes are of enormous size and most perfect construction, and far surpass in both respects those of all other annelids.

In thus being blind or provided with extraordinary organs of vision, the members of the pelagic fauna resemble those of the deep-sea fauna, and there are other points of resemblance between the two assemblages of animals, such as that amongst both a large proportion of phosphorescent animals occur. Prof. Fuchs,[1] in lately-published most valuable papers on the Pelagic Flora and Fauna, and on Deep-Sea Life, has dwelt much on these resemblances, and concludes that they are to be explained by the circumstance that, like the deep-sea fauna, the pelagic fauna is to a very great extent a fauna of the darkness, the deep-sea fauna living where darkness, as far as sunlight is concerned, is perpetual, and the pelagic fauna being nocturnal in its habits. By far the greater part of the pelagic fauna is thus nocturnal in its appearance at the surface. In the day-time the animals composing it sink to considerable depths, and they rise only at night. Certain pelagic animals, however, seem not to mind the sunlight. Radiolarians may be seen at the surface when it is calm, in the full glare of the sun, and so may Velellas and Ianthinas; indeed these latter and some others cannot leave the surface. Some Ctenophora, especially Eucharis, according to Chun, seem rather to like the sun. Flying-fish, again, are at the surface day and night, and the beautiful pelagic fish called dolphins (Coryphæna) show their wonderful colours to best advantage in the full sunlight, as they swim lazily round a becalmed vessel. Winds and storms drive all the pelagic animals below which are capable of descending, and one may sail over wide tracts of sea during boisterous weather and imagine that the water is almost barren of life, whereas a calm night would have shown the whole surface teeming with animals.

The important question of the day with regard to pelagic life is, to what depths does it extend? How far do the animals which come up at night descend, and do any which never come to the surface extend their range below the limit of these again; and do any inhabit the region leading down to the very deep sea bottom?

Prof. Weissmann,[2] from his observations on what may be called the pelagic fauna of Lake Constance, has shown that the

[1] Th. Fuchs, "Ueber die Pelagische Flora und Fauna, u.s.w." J. C. Fischer, Wien, 1882.

[2] Das Thierleben in Bodensee. Von Aug. Weissmann. Lindau, 1877.

minute crustacea of which it is composed, slowly rise and sink just like the pelagic inhabitants of the sea. They never sink to a greater depth than twenty-five fathoms, but from this depth they rise gradually to the surface in the evening, following the limit of darkness, as the sun sets, and they descend in the same manner in the morning as the sun rises. Prof. Forel has observed the same facts in the Lake of Geneva. Now a depth of about twenty-five fathoms has been shown by Prof. Forel to be the limit at which sensitised paper ceases to be acted upon by direct sunlight in the waters of the Lake of Geneva. Below this depth no sunlight penetrates. Prof. Weissmann, after trying all other apparent explanations, concludes that the reason why the pelagic crustacea oscillate perpetually in this curious manner in depth is in order to economise the light and be able to feed during the twenty-four hours over their whole possible range of feeding-ground. Were they to remain at the surface during the daylight they could not see at all to feed in the depths in the weak light at night. This most ingenious explanation will no doubt apply equally well to all the marine pelagic animals with well-developed eyes, and which feed on the nearly stationary vegetable matter and *débris* held in suspension by the surface strata of the waters. Whilst the numerous blind forms which execute similar diurnal oscillations, such as the Ctenophora,[1] Echinoderm larvæ,[2] Pteropods, and others, must follow the crustacea and other small fry to feed upon them. Indeed the whole pelagic fauna is so closely inter-dependent, that it must needs move together. It is very probable that some forms come to the surface only at night, because thereby, like so many other nocturnal animals, they escape many possible enemies by always keeping in the dark.

Dr. Chun has observed that the Ctenophora of the Gulf of Naples, after being abundant in spring, become extremely scarce and almost disappear during the three summer months, and re-appear suddenly again in great numbers in the autumn. He believes, from having caught them in the summer at considerable depths, that these Ctenophora descend annually at the end of spring in order to feed on the minute crustacea which then remain in deep water (very possibly because the more powerful light allows them then to feed at the lower level), and that, having become fully fed up, and the young having in the depths passed through their metamorphoses and reached the adult condition, they rise together to the surface, and appear in a swarm as if by magic. One of the Ctenophora with this habit is the beautiful venus girdle (*Cestus veneris*). Scypho Medusæ (*Cassiobeia Borbonica*) and other pelagic animals, appear to perform the same periodical migration in depth. Doubtless similar annual migrations in depth occur amongst pelagic animals in various parts of the world, and this may account for the extraordinary scarcity of some few.

It appears probable, therefore, that pelagic animals perform oscillations in depth from three different causes. They perform, firstly, diurnal oscillations in accordance with the changes in light and darkness; these, secondly, are liable to constant interruptions from the occurrence of boisterous weather; and thirdly, they may alter their depth periodically, according to the season of the year.

The great inland fresh-water lakes have each a regular coast or littoral fauna, a deep-sea fauna, and a pelagic fauna, just like the oceans. The pelagic animals of the lakes resemble those of the sea in many interesting particulars. They are, like them, hyaline and transparent, of most curious forms, modified for a constantly swimming existence, and sometimes possess immensely developed eyes. I shall throw on the screen figures of two crustaceans from the pelagic fauna of the Lake of Geneva, from Prof. Weissmann's figures. Both are Cladocera or water-fleas, of the one-eyed family, Polyphemidæ. The first, Bythotrephes, is of most extraordinary shape, having an enormously long tail spine to balance its top-heavy body; it is transparent like glass, but in late autumn becomes covered with beautiful ultra-marine spots. It has a single enormous compound eye in front, and in the brood pouch, under the rounded carapace on the back is born a single egg. The second, *Leptodora hyalina*, is also of most extraordinary form; it is absolutely transparent, like Bythotrephes, and almost invisible in a glass of water. It has an enormous pair of feathered rowing antennæ to sustain it in the water. This curious animal, as well as a species of Bythotrephes, has lately been discovered by Mr. Conrad Beck in Grasmere Lake, in Westmoreland, together with other Cladocera, so that our own lakes have their pelagic fauna. *Leptodora hyalina* had previously been found by Mr. Bolton in the Olton reservoir near Birmingham.[1]

But the most important question, as I said before, is to what depth do the pelagic animals of the ocean descend? This has remained an unsolved problem ever since it first exercised the mind of the great Johannes Müller, though in his time the question was a different one, being directly connected with that of whether there was any life at the deep-sea bottom or not. An open net sent down to any depth, as it comes up may catch animals at any intermediate depth. Hence it is impossible to assign to any particular depth with any certainty any animals found in a tow-net when raised to the surface. What is required is experiments made with a net so constructed as to be sent down closed to a certain depth, then opened, then towed for some distance, and then raised again to the surface. Such a net has been devised by Capt. Sigsbee, of the U.S. Navy, the inventor of nearly all the best deep-sea apparatus now in vogue, and has been used by Mr. Alexander Agassiz, who found that the pelagic animals on a calm day extended pretty uniformly downwards from the surface to a depth of 50 fathoms, but that at depths of more than 100 fathoms nothing was to be caught at all. Unfortunately very few experiments have as yet been made by Mr. Agassiz with the instrument, and therefore no final conclusions can be drawn from them. We look forward with the greatest interest to further prosecution of similar researches.

On the other hand there is evidence pointing to a further extension in depth of deep-sea forms. On board the *Challenger* my colleague, Mr. John Murray, throughout most of the voyage, made very numerous experiments with the tow-net at great depths, and so constantly obtained very different results by these means to those which were shown by nets simultaneously worked at intermediate depths that he is firmly persuaded that the Pelagic Life extends to very great depths, indeed certain animals which he caught such as the Phœodaria which have been described by Prof. Haeckel, were obtained only from nets which had been down to very great depths. It is indeed possible that there is a direct connection between the deep sea fauna and that of the surface and that the young of certain deep sea fish pass their early existence at the surface amongst the Pelagic throng. It is known with certainty that the young of many fish living in tolerably deep water, such as the cod, inhabit the surface water in their early stages, and it is possible that the eggs of fishes living at great depths may similarly rise to the surface for development. Prof. Lütken[2] has described a small fish which was obtained from the stomach of an albacore which appears without doubt to be the young of a deep sea Lophoid, probably *Himantolophus rheinhardtii*, and the young of other deep sea fish have been found under similar circumstances.

Mr. Agassiz, whose authority on the matter is of the greatest weight, is nevertheless convinced[3] "that the surface fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt so to speak of animal life between those animals living on the bottom or close to it and the surface Pelagic fauna." If this be the case then the limit in depth from the surface must be ultimately due to the limit in the penetration of sunlight, and consequent growth of vegetable organisms. Over this belt the ultimate source of food of the Pelagic and deep sea animals is concentrated; below it a constant rain of organic *débris* is always falling slowly,[4] through an immense interval of absolute darkness to the deep sea bottom, but this rain thus spread out is sparse, and being so, it could scarcely be obtained by animals devoid of or unable to employ vision in sufficient quantity to support life.

If the intermediate zone is permanently inhabited at all, such habitation probably depends on the phosphorescence of the animals dwelling in it whereby they are able to use eyes and pick up the scanty food. It is quite possible that some of the fishes endowed with phosphorescent organs such as the Scopeli which, as Dr. Günther reports were brought up in the *Challenger* nets "from any depth to 2,500 fathoms," and some of which occur on the surface, may roam through the intermediate zone finding food by means of their own light, and that may be the

[1] Dr. Carl Chun, Fauna and Flora des Golfes von Neapel. Ctenophora, s. 239.
[2] A. Agassiz, North American Star Fishes. Mem. Mus. Comp. Zool. Harvard, 1877, p. 28.

[1] E. Ray Lankester, *Ann. and Mag. Nat Hist.*, January 1882, p. 53.
[2] Vidensk. Selsk. Skr., 5te Række 11te, Bd. v.
[3] Bull. Mus. Comp. Zool. Harvard, Vol. VI., No. 8, p. 153.
[4] By experiment I found that a dead Salpa would take about four days to reach the bottom in a depth of 2,000 fathoms. ("Notes by a Naturalist on the *Challenger*." Macmillan, 1879, p. 582.)

reason why they bear the peculiar organs they do, but the food must be so infinitely more scanty over this intermediate zone than in the upper stratum that life cannot be abundant in it anywhere, and no arrangement such as probably exists at the deep sea bottom whereby unphosphorescent animals profit by the phosphorescence of others can occur. At the ocean bottom the organic *débris* falling from above becomes again concentrated and compressed into infinitely less space than in the surface zone, and life in abundance becomes possible again. The existence of a deep sea fauna at any great distance from coasts depends upon that of a Pelagic fauna overhead.

With a net capable of acting like that of Captain Sigsbee a vast amount of most interesting investigation lies open. We know as yet next to nothing certain as to the curious oscillations in depth and migrations of the Pelagic fauna. The matter would be a very pleasing subject for research for any yachtsman so disposed, who would care to investigate the movements of the surface fauna of our coasts, and I would urge any here present to take it up.

With regard to the connection between Pelagic and Deep-Sea Life, a most important question is the still unsettled one as to the true origin of the Globigerina mud by which so vast an area of the ocean bottom is covered. As is well known, Globigerinæ and other Foraminifera with calcareous shells occur in abundance at the surface of the ocean. They were originally discovered there by Johannes Müller, who was the first to observe in the Mediterranean off the French coast the Pelagic Globigerina and Orbulina which are provided with long fine calcareous spines all over their shells, on which to extend their gelatinous tissue and thus by increasing their volume enable themselves to float. Other surface forms are devoid of spines. The well known Globigerina mud is made up mainly of such shells, and the question is whether the main part of this important deposit is derived from the surface, or whether on the contrary the shells composing it belong to animals living on the deep-sea bottom. Mr. John Murray who spent the whole of the *Challenger* voyage and most of the time which has elapsed since in investigating the surface fauna, and comparing with it the deep-sea deposits writes to me, that he is convinced that in a pure Globigerina mud not 3 per cent. of the carbonate of lime it contains is derived from organisms living on the bottom. On the other hand, Mr. H. B. Brady, the great authority on Foraminifera still seems from the tenour of his short report on the Foraminifera of the *Knight Errant* Expedition, to hold an opposite opinion,[1] although he evidently wavers somewhat.[2] The sarcode contained in the undoubtedly living surface globigerinæ is tough and readily preserved in alcohol. It remains firm after the shell has been removed by acids, and may be readily stained with carmine. There is no reason why the sarcode of deep-sea specimens should not be demonstrated with equal ease, yet it is only very rarely that any is found in them, and even then it appears not to be definite and fresh like that so readily procured from surface specimens, and constantly to be seen in other Foraminifera which certainly live at the bottom. I have never discovered any satisfactory trace of it myself, though I have often sought for it in fresh specimens of globigerina mud. The question whether any form of Globigerina does or does not live on the deep sea bottom is one which still urgently requires a definite answer. The subject of the origin of the Globigerina mud is ably discussed by Butschli,[3] in his account of the Protozoa now in course of issue. One of the principal difficulties in the matter is that much thicker Globigerina shells are found on the bottom, than are met with at the surface. He suggests that the additional thickness may be added to the shell as the animal becoming heavy gradually sinks into deep water out of reach.

An important geological question is connected with the deposition of the Globigerina mud. Prof. Haughton, Dr. Croll, and more lately Mr. Wallace in his "Island Life," have made attempts to arrive at the age of the sedimentary rocks by calculating the time during which a deposit of the mean thickness of the stratified rocks of the globe would be formed on the sea bottom at the present average rate of denudation. In working out this problem Prof. Haughton regarded the materials as spread uniformly over the entire sea bed, whereas Dr. Croll and Mr. Wallace maintain that all the deposit worth consideration may be regarded as taking place within a comparatively short distance of the coast, Mr. Croll believing that the deposit taking place beyond a distance of 100 miles on an average is not very great, and Mr. Wallace reducing the area of hypothetical deposition to a very much less breadth. Now both of the latter observers seem to have forgotten that the whole of the organic deep-sea deposits, all over the ocean beds must be taken into consideration in any such calculations, quite as much as any deposits of insoluble silts which may be formed near shore. The vast deposits of calcareous globigerina mud, the siliceous Radiolarian and Diatomaceous deposits and the abundant red clays of the still deeper areas are as much the products of the present denudation of the earth's surface, as the banks formed near the river mouths. There is no other source from which they can be derived. A considerable amount of the results of denudation is carried by the rivers into the ocean in solution, and a further quantity doubtless becomes dissolved by the sea water when the river water is mixed with it, and the Pelagic Foraminifera and other animals assimilating it carry it far from the coasts all over the oceans and deposit it in the deep sea, spreading it evenly over the bottom.

A large quantity of the sedimentary rocks taken into consideration in one side of the calculations referred to, resemble the deep-sea deposits in being mainly ultimately or directly deposited through organic agents.

I cannot but think that some modification of the results attained in the calculations referred to may be required on this consideration, and life allowed to add a few more tens of thousands of years to her age.

The whole existence of the Pelagic fauna depends on the denudation of the land, were it not for this the supply of mineral matter in the sea water would have become exhausted long ago.

The Pelagic animals prey upon one another largely. The voracity of some of the most harmless looking jelly-like forms is extraordinary, Dr. Chun describes the Ctenophor Beroe as swallowing another Ctenophor much larger than itself with the greatest rapidity distending its body enormously in the act. Many of the larger pelagic animals, like the whalebone-whale, feed on large quantities of minute animals, Prof. Steenstrupp has found that certain Pelagic Cephalopods feed on minute crustacea and the use of the wide conical membrane surrounding the arms in the Cirrhoteuthidæ is apparently to catch shoals of Entomostraca. Similarly the Penguins of the southern sea seem to feed largely on minute crustacea. Their stomachs are to be found crammed with them. In catching them they move through the water with immense rapidity, and all such feeders are endowed with immense muscular power. Other pelagic Cephalopods may be seen at the surface in droves pursuing shoals of fish and squirting the water from their funnels into the air in small jets in all directions.

A most remarkable fact is that certain larval forms of shore animals undergo extraordinary modifications under the influence of Pelagic existence. The best known instance in point is that of the Leptocephali, which are small ribbon-shaped fishes absolutely transparent, and in many cases devoid of any hæmoglobin in their blood, whilst the slight skeleton they possess is cartilaginous only, and the whole tissues are soft and pulpy. They are often abundant at the sea surface far from land, but are never found sexually mature. There seems to be no doubt that the most abundant of these forms are the young of conger eels, but off many coasts, as for example, that of Norway, where congers are abundant, no Leptocephali are ever found. Dr. Günther's conclusion is that all these curious fish are the results of the abnormal development of the larva of various fishes (possibly sprung from eggs accidentally shed at the surface instead of the bottom), which continue to grow to a certain size without corresponding development of their organs, and perish without ever becoming mature.

Another instance of similar modification is that of the young flat fish termed Platessæ, which are like the Leptocephali perfectly transparent. These are also often taken in the open ocean and it appears probable that when thus placed under unnatural circumstances their development becomes arrested, and many probably perish eventually, like the Leptocephali, without the arrangement of their eyes ever becoming unsymmetrical. The deep sea is devoid of flat fish and it seems impossible that the larvæ should ever find their way back to shore.

In the case of the young of the Flying Gurnet something analogous occurs. In the minute young a reversion to the ancestral condition is exhibited, the pectoral fins are not longer in proportion to the fishes' body than those of other fish, they only begin to develope into wings when growth has proceeded

[1] Exploration of the Faroe Channel during the summer of 1880, by Staff Commander Tizard, R.N., and John Murray. *Proc. R. S. Edin.*, 1881-82, p. 80.

[2] Notes on Reticularian Rhizopoda (*Quart. Journ Micros. Sci.*, 1881, p. 67.

[3] Bronn Klassen u. Ordnungen des Thierreichs, Protozoa, 1880, p. 166.

very far, but as Prof. Lütken[1] has shown the degree of development of the pectoral fins bears no constant relation to the size attained by the young fish, a great increase in size may occur without a corresponding progress in metamorphosis. In consequence of this the young of the common flying Gurnet *Dactylopterus volitans*, were not for long recognised as such but were considered distinct and named Cephalacanthus. A parallel instance to that of Leptocephalus is possibly that of the curious flattened larva of the Rock Lobster (Palinurus) Phyllosoma, which is also found in the open ocean attaining sometimes gigantic proportions. Possibly also other pelagic larvæ become thus hypertrophied in the larval condition. We may compare with these phenomena the somewhat parallel modifications which occur naturally or may be produced artificially amongst larval Amphibians.

Many of the Pelagic animals carry with them parasites similar to those affecting their littoral allies and which thus are, as it were, imported into the Pelagic fauna, but there are a few definitely pelagic parasites parasitic upon pelagic hosts. The young of the Pelagic annelid Alciopa are parasitic within the bodies of Ctenophora, there is the small parasitic Hydromedusa Mnestra, which adheres to Phyllirhoe, and lastly there are the young Cunina medusæ which cling in dense clusters within the stomach of the Geryonid Medusa Carmarina, and were at first imagined to be the young of the Carmarina itself.

A remarkable feature about Pelagic animals is that very many of them occur in large swarms, some in immense hosts. Further Velellas, Porpites, and Ianthines are always met with in schools, and even Leptocephali, and very many other forms are usually caught in the tow-net, several at a time.

In their almost universal geographical distribution except as regards the colder seas, Pelagic animals resemble the deep-sea fauna; as examples it may be mentioned that according to Prof. Lutken, the tunny of the Mediterranean is identical with that of Japan, and the albacore of the Atlantic with that of the Pacific. Pelagic genera seem to be of almost ubiquitous distribution, though the Atlantic and Pacific species frequently differ.

Some few Pelagic forms seem to be remarkably scarce. As an instance may be cited Pelagonemertes, the curious Pelagic Nemertine with a ramified intestine. This form was obtained in great abundance by Lesson at the surface in 1830, between the Moluccas and New Guinea. By the *Challenger* it was found twice, only a single specimen being got on each occasion. The first was caught to the south of Australia, and the second on the coast of Japan. The animal seems never to have been met with by any one excepting on these three occasions. On each occasion when caught by the *Challenger* it was found in a trawl which had been down to a great depth. It is therefore very possible that it very rarely rises to the surface.

Similarly many Pelagic Cephalopods though known to exist in multitudes are of the greatest rarity, being only known from fragments. Bushels of their horny beaks are found in the stomachs of whales, which subsist on them, and several genera are known to Prof. Steenstrupp only from these quantities of beaks. He has never seen a trace of any other part of them.

Notwithstanding the wide distribution of Pelagic forms, Mr. Murray finds that he is able to form tolerably correct conclusions as to the latitude of any sample of deep-sea bottom which contains organic remains submitted to him, from the nature of the Pelagic debris of which it is composed. He can also form some idea of the depth from which a deposit has been brought up by observing the extent to which the substance of the calcareous shells has undergone solution. Pteropod shells owing to their extreme thinness appear to be dissolved first, and disappear say at 1200 fathoms, then the finest globigerina shells at 2200, then the larger globigerina shells and so on.

Pelagic animals as a rule appear to be extremely sensitive to any lack of saltness in the water. The surface fauna of the Baltic is thus very poor, and in the upper part consists of little else than a few small crustacea, but curiously enough the large Scyphomedusæ, such as Aurelia and Cyanea appear to be unaffected injuriously by a brackishness of the water but rather to prefer it. They extend in the Baltic into places where the water is very little salt and I have seen similar large Scyphomedusæ swimming in shoals at the head of one of the large creeks of the Hawkesbury inlet in New South Wales, in the actual current of a small fresh-water stream which ran in and where the water was quite drinkable. This is all the more remarkable because as Mr. Romanes has shown the one Hydromedusa which we know of as confined to fresh water, the well known Lymnocodium of the Victoria lily tank in the Regent's Park Botanical Gardens, is excessively sensitive to any addition of salt to the water in which it is.

I am informed by Mr. George Baden Powell that the large Medusæ so abundant here at Southampton, shows a curious tendency to crowd up towards the higher part of Southampton water. There are hardly any to be found as a rule in the Solent but they appear always to tend to crowd up at the heads of estuaries. I have noticed in Norway also that they appear to crowd at the heads of the Fjords.

I shall now proceed to some remarks on the zoological composition of the Pelagic fauna and its probable history in the past. The present Pelagic fauna may be regarded as consisting of two constitutents, firstly, a number of species belonging to a series of orders and subclasses which are absolutely peculiar to it, that is to say, which have no representatives which are littoral or terrestrial, and are not at any period of their existence other than Pelagic. We may reckon about nine such groups. There is no group which rises undoubtedly to the rank of a class which is thus Pelagic only. The groups are as follows, the Siphonophora, Ctenophora,[1] Chætognatha, Heteropoda, Pteropoda, Larvalia, Salpæ, Pyrosomidæ, Cetacea.

Of the antiquity of the Siphonophora we know nothing directly, for they do not occur at all as fossils, and as they are like most pelagic forms ill adapted for preservation as fossils, it is impossible to conjecture whether they are of quite modern or of ancient origin. They are complex colonies of animals of various forms united together and performing separate functions for the common good of the colony. They are offsets of the Hydromedusæ, and thus derived originally from a pelagic planula ancestor, but it seems uncertain whether they have subsequently sprung from a once fixed hydromedusa stock set free, or have been free and pelagic throughout their history. The Ctenophora are also an offset from the Hydromedusæ; they also have as yet no geological history. Their ancestors have probably always from the planula upwards led a free pelagic life. The history of the Chætognatha (Sagitta) is obscure. The Heteropods and Pteropods are derived from a common pelagic veliger ancestor which existed as early at least as Silurian times, and this ancestor probably descended from a trochosphere also pelagic.

The Larvalia, the Ascidian Appendicularia and its allies, near relatives of the ancestral vertebrata, probably have always been Pelagic and have existed in something like their present form from a very early period, whilst the Pyrosomidæ after branching off from the same stock as simple animals have possibly undergone a fixed sessile condition as compounds before becoming again Pelagic.

If Prof. Ray Lankester is correct in his suggestion (in his British Association lecture on "Degeneration") that very possibly an ancestor of all the vertebrata, including man himself was once pelagic, because the peculiar mode of the development of the eye of vertebrates can only be accounted for by the supposition that the tissues of the head were completely transparent and from other considerations; then the whales are now so to speak for the second time pelagic in the history of life. Their more immediate ancestors, allies of the seals, and sprung from the common progenitor of the stock of placental mammals, took afresh to the sea and gradually relinquished the shore altogether.

The second division of the Pelagic fauna is composed of numerous representatives of various classes and orders of animals, the majority of members of which are inhabitants of the sea bottoms, shores or land surfaces, but which representatives are mostly specially modified in remarkable ways to fit them for pelagic existence. Only a few of these can now be touched on. Although there are abundance of Cilioflagellata which are pelagic, there seem to be very few true Infusoria (or Ciliata) which are so, at least very few have as yet been recorded as such, and none at all known from any great distances from land. The few as yet known all belong to one family of the Peritricha, the Tintinnidæ. Codonella, one of them, of which a representation is now on the screen, is bell-shaped and remarkable for being provided with a siliceous protecting shell.

There are even sea anemonies which have taken to Pelagic existence, and are to be found in great quantities on the ocean surface at times. They are exactly like the ordinary sea anemonies of our shores, excepting that their base instead of

[1] Ch. Lutken, Spolia Atlantica. Copenhagen, 1880, p, 426.

[1] It is possible as suggested by the late Prof. Balfour, that Kowalensky's Cœloplana may prove to be a creeping Ctenophor.

being flat for adherence to rocks is closed in so as to hold a small mass of air. Suspended by the buoy so formed, they float at the surface mouth downwards. The one of which a figure is now on the screen *Minyas cærulea*, is remarable as being one of the small band of Pelagic animals which is coloured deep blue. There are also Pelagic insects of the genus Halobates of the Bug family, and closely allied to the common water bugs which skip on the surfaces of our ponds. Halobates is found clinging to the surface of the waves at all distances from land in the open oceans, and outrides the heaviest storms.

There are many Pelagic fishes; I have already shown you the dolphin (Coryphæna). Here is a figure of one of the Ribbon Fishes, the scarce Regalecus. This fish has usually been supposed to be a pelagic fish, but Dr. Gunther is persuaded that it is a true deep-sea fish, though it has not yet been caught in any deep-sea net, only picked up dead on the surface. There are many similar fishes about which some difference of opinion as yet exists as to their habits. The young of the Ribbon Fishes are found alive at the sea surface, and the group may therefore perhaps yield another instance of the connection of Pelagic with deep-sea forms. The Pelagic snakes are interesting as, to some extent, modern representatives of the Eocene sea serpents (Titanophis), for though they come on shore to produce their young, their existence is mostly spent at the sea surface often far from land, and they are specially modified both in the structure of their lungs, and the ribbon-like flattening of their tails for pelagic existence.

There is one lizard, the well known Amblyrhynchus of the Galapagos Islands, described by Mr. Darwin in his Journal, which though it cannot in any way be termed pelagic swims out to sea, and as the only recent one which does so is worth mention as a sort of representative of the gigantic pelagic lizards of Mesozoic periods such as Mososaurus.

With so many groups of the animal kingdom contributing to the Pelagic fauna, it is remarkable that some large groups should be entirely unrepresented within it. There are no adult Pelagic sponges, no Alcyonarians, no Sipunculids, no Brachiopods, no Lamellibranchs, and lastly no Echinoderms. Considering the curious adaptations to Pelagic life which have been undergone by such forms as sea anemonies, nemertines, compound ascidians and gasteropods, it is most easy to conceive how Lamellibranchs for example taking after the habit of flying as it were butterfly fashion through the water like *Lima hyans*, might have become Pelagic, and how Echini taking after Minyas, or Comatulæ swimming with their arms or Holothurians in various ways might have assumed a Pelagic dress, but no Lamellibranch, and no Echinoderm seems ever in the long record of the past to have been Pelagic since the time of their earliest Pelagic ancestors, unless possibly Saccoma of the lithographic state was Pelagic.

With regard to the history of the Pelagic fauna in the past. There can be no doubt, as Prof. Weissmann so well puts it, that "the birth place of all animal and plant life lay in the sea." It is probable that a considerable part of earliest life which existed must have been Pelagic, and that the ancient Pelagic fauna was to a large extent the parent of all other life. The developmental history of all marine animals points clearly in this direction, closely similar transparent Pelagic larval forms being common to groups of widely different adult littoral forms. The resemblance between the larvæ of these adult forms can hardly be conceived to have been arrived at by natural selection after the adult forms had already diverged from one another. It is only to be explained on the hypothesis of an original Pelagic ancestral condition. One of tire Monera, Protomyxa aurantiaca, is even now a Pelagic form, having been found by Prof. Haeckel adhering to a floating spirula shell.

From the recent interesting researches of Dr. Nathorst,[1] we know that Scyphomedusæ closely like those now swimming in Southampton Water, were already amongst the Pelagic fauna of the Cambrian Sea, whilst the mud at the same time swarmed with annelids very similar to those now existing. At the same remote epoch Brachiopods, Corals, Echinoderms, Crustacea, and other forms were already present on the coasts.

The Precambrian Pelagic fauna must therefore probably have contained sexually mature representatives of the Planula, the Bilateral Echinoderm larva, the Ephyra (which survives as such to the present day), the Trochosphere and the Nauplius. During the Cambrian period or earlier, was added the Cypris ancestor of Cirripeds, and the vertel rate ancestor, and the Trilobite Æglina with gigantic eyes found its place in the dim light somewhere, possibly amongst the Pelagic fauna. In Silurian times Pteropods were added to the Pelagic throng, some gigantic forms of which nearly a foot in length are now extinct, whilst one genus then present still flourishes in modern seas, the Heteropods also appeared (Bellerophon) and Cirriped larvæ, and the Graptoliths, possibly Pelagic, appeared and became extinct. In the Devonian period certain sharks and rays and ganoid fishes probably took to Pelagic life. Pelagic representatives of the sharks and rays still flourish, but the ganoids have retreated to the fresh waters. In the early Secondary period Globigerina appeared and a few Radiolarians, and the dibranchiate cephalopods came into being and soon the sea swarmed with the Pelagic Belemnites. The air-breathing reptiles whose ancestors had quitted sea life and gone on shore came back to Pelagic life and the Ichthyosaurus with enormous eyes chased the Pelagic prey in the depths, or hunted at night. Somewhat later the ancestors of the Mososaurids took to the sea; and their progeny became entirely Pelagic and as huge as whales.

In early tertiary times, or shortly before that, various mammalia took to the sea, and amongst them the whales became entirely pelagic and relinquished the shore altogether. Some animals have apparently taken to oceanic life, in very recent times indeed. Ianthina is an instance in point, it has not as yet been discovered in the fossil condition at all, nor any close allies of it.

Somewhat thus has the Pelagic fauna grown up, having been partly composed of animals: the ancestry of which has probably led a Pelagic life from the earliest times, and partly added to, at all ages by inhabitants of the coast, and the dry land which have as it were from time to time run away to sea.

In conclusion, I can only say that it has given me the greatest pleasure to address a lecture to you on the present subject in a city, the population of which is itself so largely Pelagic. It is to a considerable extent through the careful collecting of the Captains of merchant vessels interested in zoology on the high seas, who have gathered specimens for the Museums of their home ports, that many of the facts I have laid before you to-night have been brought to light, and all praise is due to them for the fact.

[1] Svenska Vetensk. Akad. Hand., No. 7, Bd. xviii.

UNDERGROUND TEMPERATURE

THE Underground Temperature Committee of the British Association have presented a summary (drawn up by Prof. Everett) of the results contained in all their reports (fifteen in number) up to the present date, of which the following is an abridgment:—

The results are classified under the heads: A. Instruments. B. Methods of observation. C. Questions affecting correctness of observations. D. Questions affecting deductions from observations. E. Comparison of results. F. Mean rate of increase of temperature with depth, and mean upward flow of heat.

A. INSTRUMENTS.—Under this head we have: 1. Instruments for observing temperature. 2. Subsidiary apparatus.

1. The thermometers which the Committee have employed have been of two kinds—slow-action thermometers and maximum thermometers. The present pattern of slow-action thermometer consists of a thermometer having its bulb surrounded by stearine or tallow, the whole instrument being hermetically sealed within a glass jacket, and had its origin in a conference between the secretary and Dr. Stapff in the St. Gothard Tunnel.

Our present patterns of maximum thermometer are two—the Phillips, and the Inverted Negretti—both being hermetically sealed in strong glass jackets to prevent the bulbs from receiving pressure when lowered to a great depth in water.

Both instruments are used in a vertical position, and they register truly in spite of jolts in hauling up.

References to Becquerel's thermo-electric method of observing underground temperature were made in three of the reports, and some laboratory experiments were subsequently carried out by the secretary, which led to the conclusion that the method could not be relied on to yield sufficiently accurate results. It may be mentioned that Becquerel's observations are only carried to the depth of 100 feet, whereas we require observations at the depth of 1000 or 2000 feet.

2. Under the head of subsidiary (that is non-thermometric)