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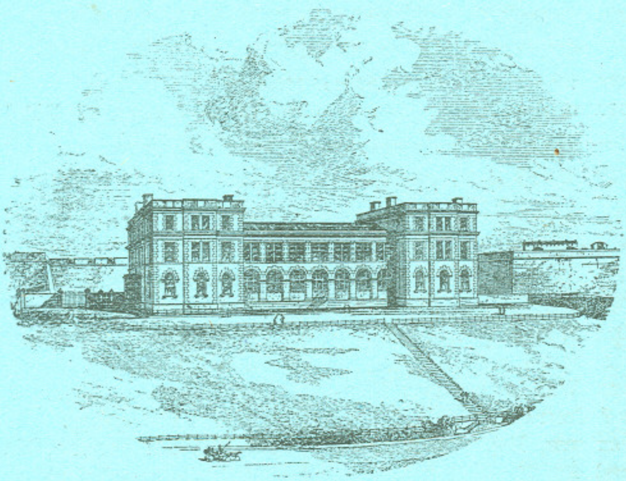

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Contributions to Marine Bionomics.

By

Walter Garstang, M.A.,
Fellow and Lecturer of Lincoln College, Oxford.

I. The Habits and Respiratory Mechanism of Corystes cassivelaunus.

Corystes cassivelaunus is a crab of unusually narrow and elongated form, which has received the popular name of "masked crab" from the grotesque resemblance which its sculptured carapace bears to a human face. It is common round all the coasts of the British Isles, and, although normally an inhabitant of the deeper water, is occasionally found at home in sandy pools on the sea shore, and is frequently cast up in hundreds on sandy shores after heavy gales.

I. Systematic Position.

The systematic position of the Corystoidea has long been a disputed point among carcinologists. Henri M. Edwards (1834) placed the Corystoid crabs near the Dorippidæ among the Oxystomata, and regarded them as connecting links between the Cancroidea (*viâ* the Calappidæ) on the one hand, and the Anomoura on the other.

De Haan (1849) removed the family from the group Oxystomata altogether, and placed it with the Cyclometopa and Catometopa of M. Edwards, in a separate sub-division of the Brachyura, the Brachygnatha.

Dana (1852) made of the Corystoidea an independent and primary tribe of the Brachyura, distinct from the Cancroidea and Leucosoidea alike.

Alphonse Milne-Edwards (1860) reverted to the older view, and placed the Corystidæ near the Calappoid Oxystomata. Heller also (1863) placed the Corystidæ among the Oxystomata.

Finally, Claus (1880) definitely placed the Corystidæ in the Cyclometopa. In this he has been followed by Miers (1886) and Stebbing (1893).

It cannot be said, however, that the real position and affinities of the Corystidæ are yet established. The reason for this uncertainty is probably due to the fact that, as will appear further on, the structure of these animals is remarkably modified in relation to sand-burrowing habits. Some of these adaptive modifications of structure, which reappear in certain other groups of Crustacea, have undoubtedly impressed the minds of certain writers with ideas of homology and genetic relationship between the Corystidæ and groups having no real affinity with that family. The case affords a new illustration of the inadequacy of the purely morphographic method, when unchecked by considerations of functional adaptation, for the solution of problems of relationship and genetic classification.

II. Structural Peculiarities.

The structure of *Corystes cassivelaunus* is noteworthy on account of the following features. The second antennæ are greatly elongated—as long as, or longer than, the body—and are fringed along their entire length by two rows of hairs, one of which runs along the ventral, while the other runs along the dorsal border of the antenna. The hairs of each row curve inwards towards those of the corresponding row on the second antenna of the opposite side. The second antennæ shew a marked tendency to approximate to one another longitudinally; the opposing rows of hairs then interlock, with the resulting formation of a median tube, the lateral walls of which are formed by the jointed flagella of the antennæ, while the dorsal and ventral walls are fenestrated along their whole extent by the interspaces between the interlocking hairs. The organ formed by the apposition of the second antennæ I shall term the "antennal tube."

The long axes of the three stout basal joints of the second antenna are disposed at right angles to one another, and bring about a characteristic double bend in the basal part of the antenna. The double row of hairs found on the flagellum of the antenna is continued backwards along these three basal joints. The hairs on the most distal of the three joints interlock with those of the corresponding joint of the opposite antenna; the hairs on the anterior face of the deflected middle joints bend inwards towards the median line along the sides of the rostrum, and together with a median triangular tuft of hairs springing from the rostrum itself, form the hairy roof of the proximal part of the antennal tube.

The antennal tube opens posteriorly into a rectangular chamber in front of the mouth. This "prostomial chamber," as it may be termed, is roofed by the rostrum in front, the antennal and epistomial sternites in the middle, and the prelabial plate behind. It is flanked by the two basal joints of the second antennæ in front, and by a forward process of the pterygostomial region of the carapace behind. Its floor is imperfect, and is formed by the anterior part of the third maxillipeds behind, and by a quadrangular sieve in front, furnished by the hairs springing from the two basal joints of the second antennæ, the anterior pterygostomial processes, and a special anterior process of the fourth joint of the external maxillipeds. The hairs from all these parts are directed inwards towards the centre of the quadrangular space outlined by the boundaries of the prostomial chamber, and constitute a complete sieve-like floor to the chamber in question. On each side this prostomial chamber leads by a wide aperture into the branchial cavity.

The participation of the epistome together with the prelabial space in the formation of a prostomial chamber is one of the features which strongly distinguishes the Corystoid crabs from typical Cyclometopa, Catometopa, and Oxyrhyncha. The arrangements of these parts approximates in some respects to that found in the Oxystomata, where the buccal frame or the peristome is prolonged anteriorly as a definite prostomial chamber to the very tip of the snout. This chamber in the Oxystomata, however, is completely closed in by the third maxillipeds, and is very narrow anteriorly; in the Corystoidea, on the other hand, it is broad in front, and is imperfectly closed by the third maxillipeds.

III. Previous Observations on Habits.

In Bell's "British Stalk-Eyed Crustacea" (1853) a brief reference is made to the sand-burrowing habits of *Corystes cassivelaunus.* Couch had already described the crab as "burrowing in the sand, leaving the extremities of its antennæ alone projecting above the surface." The actual process of burrowing appears not to have been observed at the time when Bell wrote, for he quotes Couch's suggestion that the elongated antennæ possibly "assist in the process of excavation." This theory of the function of the antennæ was subsequently rejected by Gosse (1865), as a result of his own observations on the habits of the crab, and again by Hunt (1885), who correctly states that the crab descends into the sand backwards with the greatest agility, "thus leaving the antennæ no opportunity of assisting in the operation."

The first writers to offer anything approaching a real explanation of the use of the antennæ were the veteran naturalist of Cumbrae, Mr. David Robertson, and Mr. P. H. Gosse. It is difficult to say, and would indeed be ungenerous to enquire, which of these two naturalists has the priority in the matter. Gosse, in 1855, described the outer antennæ of *Corystes* as "together forming a tube" (*Manual of Marine*

Zoology, I., p. 158), but he did not apparently publish his observations in full until 1865.

In the meantime Mr. David Robertson communicated to the Philosophical Society of Glasgow, on March 13th, 1861, an interesting note on the function of these antennæ. He described the burrowing habits of the crab, and shewed that, under these circumstances, the antennal tube preserved "a free passage for the purpose of enabling the animal to carry on the process of its aqueous respiration." Mr. Robertson believed, with Gosse, that the current through the tube was exhalent in character. In another paper he stated that "he had seen the ova cast up through the opening [of the antennal tube]—the inference being that the animal had placed it by means of its claws within the influence of the current." (*Proc. Nat. Hist. Soc., Glasgow*, vol. i. p. 1.)

Gosse (1865) similarly observed that each antenna, from the form and arrangement of its bristles, constituted a "semi-tube, so that when the pair was brought face to face the tube was complete." He also carefully watched a living specimen, as it was sitting upright on the top of the sand, close to the side of a glass aquarium, and observed that the antennal tube formed a channel for a definite current of water. To quote his own words: "I immediately saw that a strong current of water was continuously pouring up from the points of the approximated antennæ. Tracing this to its origin, it became evident that it was produced by the rapid vibration of the foot-jaws, drawing in the surrounding water, and pouring it off upwards between the united antennæ, as through a long tube. . . ." "I think, then, that we may, with an approach to certainty, conclude that the long antennæ are intended to keep a passage open through the sand, from the bottom of the burrow to the superincumbent water, rendered effete by having bathed the gills; and it is one of those exquisite contrivances and appropriations of structure to habit which are so constantly exciting our admiration . . . [and] are ever rewarding the research of the patient observer."

We shall see below that while Gosse's conduit-theory of the function of the antennæ is perfectly correct, his inferences as to the function of the antennal conduit are true only to a limited extent. Gosse assumed that the habits of the crab when beneath the sand were similar to its habits when above the sand, and confined his observations to the crab in the latter condition. Experiment shews, however, that there may be a marked difference in the working of certain organs under the different conditions.

A third theory as to the function of the antennæ in *Corystes cassivelaunus* is due to Mr. A. R. Hunt (1885). He says, "I incline to think that the function of the antennæ is to maintain a communication between the buried crab and the water above, as without some such connexion there would be a risk of the animals being occasionally buried to a dangerous depth by the accumulation of sand above them. Mr. W. Thompson's statement that the antennæ in very small specimens are much longer in proportion to the carapace than in the adult harmonizes well with this hypothesis, as to ensure safety the young would have to burrow to a greater depth compared with the adults than would be proportionate to their size." Mr. Hunt was not aware of Gosse's view when he framed the above theory; but, subsequently, in a footnote to his paper, he referred to Gosse's theory as identical with his own. The two are, however, essentially distinct, if I correctly understand Mr. Hunt's language. According to Gosse's view, the function of the antennæ is to produce a tube subservient to respiration; according to Mr. Hunt's, the function of the elongated antennæ is essentially sensory, viz., to enable the buried crab to determine the depth to which it burrows. The "danger" to which Mr. Hunt refers is clearly not the danger of suffocation, but the danger of dislodgment from the sand by wave-currents. The arenicolous habits of *Corystes* are adduced by Mr. Hunt to illustrate one of the various methods adopted by marine animals for resisting wave currents—a view which, in the case of *Corystes*, I am unable to accept, partly on account of the normally deep water habitat of the crab, and partly on account of evidence given below which tends to shew that the burrowing habits of *Corystes* are adopted primarily for concealment.

IV. New Observations and Experiments.

(a) Burrowing Habits. A number of living *Corystes cassivelaunus* were placed in a series of vessels containing sand of different degrees of coarseness, and it was soon noticeable that these crabs readily burrow in fine sand, but find great difficulty in penetrating very coarse sand or gravel composed of small pebbles. Moreover, a crab that has obstinately declined for several hours to burrow in coarse, gravelly sand, will immediately bury itself, if placed in an aquarium of fine sand. In all cases the process of burrowing is effected exclusively by means of the thoracic legs. The crab sits upright on the surface of the sand; the elongated, talon-like claws of the four hindmost pairs of legs dig deeply into the sand; the body of the crab is thus forcibly pulled downwards by the grip of the legs, and the displaced sand is forced upwards on the ventral side of the body by the successive diggings and scoopings of the legs; the slender chelate arms of the first thoracic pair assist in the process of excavation by thrusting outwards the sand which accumulates round the buccal region of the descending crab. This action at the same time, no doubt, loosens the sand in the immediate neighbourhood, and

renders easier and quicker the descent of the crab into its sandy burrow. Briefly stated, in fact, the four hindmost pairs of legs are all engaged in pulling the crab downwards, while the first or chelate pair is engaged in pushing away the more superficial sand in the neighbourhood of the crab's maxillipeds. The two actions combine to drive the crab downwards and obliquely backwards. The main object of this latter motion appears to be the prevention of any forcible intrusion of sand into the buccal apparatus.

When the carapace of the crab has completely disappeared beneath the surface of the sand, the antennæ are frequently seen to be rubbed obliquely against one another for two or three strokes, whereby the hairs on the antennæ are cleansed from adhering particles. This very characteristic action of the antennæ was noticed long ago by Couch, and correctly recognised by him as a process of cleansing (*vide* Bell, p. 161). After this cleansing process, however, the crab proceeds still further in its act of burrowing, and descends deeper and deeper until nothing is visible above the sand but the most distal portion of the antennal tube.

Resting passively in its bed of sand, *Corystes cassivelaunus* spends the daytime thus concealed from all observation. In aquaria an individual will occasionally emerge and remain on the surface of the sand for some time, but this can usually be attributed to the restlessness resulting from strange conditions. I am inclined to think that if the water and sand provided be of a perfectly suitable character, *Corystes* will remain imbedded throughout the day. (cf. Robertson, l. c. *supra*).

I have noticed, however, that individuals which were inactive and concealed beneath the sand during the day, shewed a marked tendency to activity at night. I have observed on several occasions that my aquarium, containing some half-dozen of these crabs, was the scene of distinct excitement and activity late at night; the crabs had emerged from the sand, and were restlessly hobbling about on the surface, as though in search of food. Although I cannot make a final statement upon the point, all my experiences incline me to the view that *Corystes cassivelaunus* is a nocturnal animal; it conceals itself in the sand by day as a protection from sight-feeding fishes, but emerges at night for food and recreation. If these habits were absolutely constant, we should expect to find the eyes of *Corystes* undergoing retrogressive changes, as, for example, in the case of *Pinnotheres.* Such is not the case, however, for the eyes are capable of forming distinct images, as well as, no doubt, of distinguishing light from darkness.

(b) Respiratory Currents. We have seen that Gosse observed a current of water setting upwards from the buccal region of the crab

through the antennal tube, and carrying upwards the water which had previously bathed the gills. This current was caused, according to Gosse, by the "vigorous vibration of the foot-jaws." The crab observed by Gosse was sitting on the top of the sand—not beneath it.

If some sea-water be coloured by the addition of a little Chinese ink, or finely powdered carmine (the former is the better material), and if a few drops of the coloured water be added to the water in the neighbourhood of the antennal tube of a buried crab, it will invariably be found that the current which sets through the antennal tube is from above downwards, and not *vice versa*. The same current may often, and indeed generally, be shewn to exist, even when the crab is not imbedded in the sand.

It will then be noticed that the coloured water is sucked between the hairs of the antennal tube, and passes downwards and backwards to the prostomial chamber. Here, in front of the labium, the current divides into two streams, one right and one left, which pass outwards and backwards into the right and left branchial chambers respectively. Finally, the coloured stream emerges from the branchial chamber beneath the edge of the branchiostegite, not at any one point, situated either anteriorly or posteriorly, but along its whole extent, and especially between the bases of the legs.

The direction of this current through the branchial chamber is the reverse of that which has hitherto been recognised in all other Decapod Crustacea. In these (*e.g.*, *Maia*, *Cancer*, *Carcinus*, *Astacus*) the current which bathes the gills is known to enter this chamber beneath the branchiostegite, and to emerge in front by the lateral aperture at the side of the mouth. The normal peribranchial current in Decapod Crustacea is from behind forwards; I shall, therefore, term the current of the buried *Corystes* a "reversed current," and shall speak of the whole phenomenon as a "reversal" of the normal current.

Although *Corystes cassivelaunus* constantly exhibits this reversed current when imbedded in the sand, yet it is occasionally possible to observe the normal current in the same specimen when the animal is not buried. The coloured water is then rejected when added near the antennal tube; but if deposited near the bases of the legs, is sucked inwards, and eventually emerges from the branchial cavity into the prostomial chamber, and thence passes either directly to the exterior or forwards by way of the antennal tube. When the normal current is at work it frequently happens that the exopoditic palps of the maxillipeds begin to vibrate. The action of these palps still further intensifies the force of the exhalent currents, and at the same time disperses the streams of water laterally, *i.e.*, the water, instead of passing to the exterior anteriorly in an even stream, is partially diverted to the sides of the crab's body, and is scattered outwards and laterally by the vigorous lashings of the exopoditic palps.

Gosse's observations on the respiratory currents of *Corystes cassivelaunus* are thus seen to be incomplete rather than inaccurate. A current *may* be directed outwards through the antennal tube, and the effete water from the branchial chamber *may* be carried away by that channel; but such a direction of the current in *Corystes cassivelaunus* is not constant, as Gosse believed, or even usual. Moreover, when the crab is imbedded in sand, the current is always reversed, except for a few seconds now and then, when the crab desires to eject distasteful particles which have entered the prostomial chamber with the respiratory current. Under such circumstances the reversed inhalent current through the antennal tube is temporarily replaced by a forcible exhalent current. But as soon as the desired ejection has been effected, the reversed current is again set up. This voluntary inhibition of the reversed current can be easily demonstrated by the addition of carmine to the water setting through the antennæ. Oddly enough, a weak solution of Chinese ink is less distasteful to *Corystes* than a mixture of powdered carmine and sea-water.

(c) Cause of the Currents. The direction of the respiratory currents is exclusively due to the movements of the scaphognathite, the valve-like and highly muscular appendage of the second maxilla, which is known to produce the regular respiratory currents of other Decapoda. H. Milne-Edwards first demonstrated the important *rôle* played by the scaphognathite in Decapod Crustacea; and he maintained that the direction of the respiratory current was absolutely constant, *i.e.*, from behind forwards in all Decapods (1839, p. 136). De Haan (1850, p. 117) has indeed suggested that the current to the branchiæ passes from before backwards; but his remarks on this subject are obviously the result of mere inference, and are not determined by actual experiment. He states, for example, that in *Portunus* the inhalent current sets inwards not only through the aperture between the base of the cheliped and the edge of the branchiostegite, but also through the anterior aperture at the side of the mouth. Experiments on *Portunus* have shewn me that this is quite devoid of foundation; the water certainly enters—in part—through the former of these apertures, but the aperture at the side of the mouth is invariably exhalent in function.

In the case of *Corystes* I observed the action of the scaphognathite by removing the three maxillipeds and the edge of the pterygostomial fold of a living specimen. The scaphognathite was completely exposed by this preparation, and its movements were readily followed.

When the normal current—from behind forwards—was at work, the propulsion of the water could be seen to be effected by a sharp, prompt blow dealt by the posterior lobe of the scaphognathite, which was succeeded by an undulatory movement from behind forwards of the remaining part of the scaphognathite. As the crab lay on its back the anterior lobe could finally be seen to descend slowly and gently upon the anterior edge of the roof of the chamber, gliding along, and, as it were, stroking its polished surface.

When the current is reversed, however, the action of the anterior lobe is quite different; it strikes the water in front with a prompt, decisive blow, and this is succeeded by an undulatory movement of the rest of the scaphognathite from before backwards. The water lying between the valve and the roof of the chamber is thus driven backwards into the branchial cavity. The action of the scaphognathite is fairly rapid, but after a little observation, checked by the employment of coloured water to test the currents, it becomes quite easy to detect with certainty the direction of the current by inference from the movements of the scaphognathite alone.

The action of the exopoditic palps of the maxillipeds in causing currents has already been described. Such currents are purely accessory, and Gosse (1865, p. 130) and De Haan (1850, p. 117) have undoubtedly erred in assigning to the maxillipeds an important share in the production of respiratory currents.

V. Evolutional Significance.

The habits of *Corystes cassivelaunus* described above seem to me to demonstrate the adaptive nature of the entire organization of this Crustacean, and slight consideration is all that is required to enable a naturalist to recognise the utility of these adaptive features.

The burrowing habit is useful as a mode of concealment from enemies. The elongation and smoothness of the carapace, and the elongated claws of the four hindmost pair of thoracic legs, are all features usefully correlated with the specialization of the crab for a sand-burrowing existence.

The elongation of the antennæ and the arrangement of the hairs upon them, the double bend of their basal joints, the structure of the parts bounding the prostomial chamber, and the arrangement of hairs upon them, are characters which, in conjunction with the reversal of the respiratory current, adapt the respiratory mechanism of the crab in a remarkably complete manner to an arenicolous mode of life. The antennal tube enables the crab to draw its supplies of water directly from the superincumbent reservoir of water, while the arrangement of hairs is such as to constitute a sieve, keeping the sand away from the respiratory organs.

The upright position of the crab is itself a most unusual feature, and is correlated with the formation of an elongated antennal tube; the posterior position of the legs is functionally correlated with the adoption of the upright attitude.

VI. Analogies.

A reversal of the respiratory current similar to that which I have just described in *Corystes* also takes place under certain conditions in the allied form *Atelecyclus heterodon.* The habits of this crab are much more complex than those of *Corystes,* and will form the subject of a later article.

An elongation of the antennæ, and their conversion into an antennal tube by the interlocking of hairs along their margins, also takes place, as I have recently discovered, in an East Indian Crustacean, *Albunea symnista,* Fabr., which belongs to the Hippinea among the Macrura Anomala (Anomura). In this type, however, the antennal tube is formed by the first and not by the second pair of antennæ. The antennal tube has obviously been produced independently in *Corystes* and *Albunea,* and affords a remarkable example of homoplastic modification. In all probability the function of the tube is the same in both cases, but no direct observations on this head in the case of *Albunea* have yet been made.

It seems to me not unlikely that further observation of the habits of *Hippa talpoida* of the American coasts will reveal an essentially similar sieve-like function for the curiously bent and setose second antennæ of that animal.

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Physical and Biological Conditions in the North Sea.

By

J. T. Cunningham, M.A.

SUMMARY.

In my report, in the preceding number of this Journal, on my observations in the North Sea, I referred briefly to the problem of the relation between the physical and biological conditions. This problem will afford scope for investigation for some time to come, and the purpose of the present article is to discuss and compare some of the most recent additions to our knowledge of the matter. The paper by Mr. H. N. Dickson, to which I referred in my previous report, was published in the *Geographical Journal* last March, under the title of "The Movements of the Surface Waters of the North Sea," and in the *Scottish Geographical Journal*, in 1894, was published a series of papers by Professor Pettersson on "Swedish Hydrographic Research in the Baltic and the North Seas." Professor Heincke has discussed the fish fauna of Heligoland, its composition and sources, in an interesting paper in the series issued under the title of "Wissenschaftliche Meeresuntersuchungen," by the staff of the Biological Station at Heligoland, in association with the Commission for the Investigation of the German Seas, at Kiel. Professor Heincke's paper is contained in Bnd. I., Hft. 1 of this series (1894), and in the same volume are a number of papers dealing on similar lines with other divisions of the marine fauna of the Heligoland Bight.

It will be most convenient and logical to start the present discussion with a consideration of the results of Professor Pettersson's work. He found that the Skagerack and Cattegat were filled with layers of water distinguished from one another by differences of salinity, and that the lower layers entered the channel as under-currents, and could be recognised at the surface somewhere in the North Sea.

The different waters he distinguishes are the following:

1. Ocean-water of 35 per thousand salinity or more.

2. Water of from 34 to 35 per thousand salinity. On account of its extension over a great part of the North Sea, this is called North Sea water.

3. Water whose salinity is 32 to 34 per thousand. This forms a broad edging along the coasts of Holland, Germany, Denmark, and Norway, and is named by Pettersson "bank-water." I shall prefer to distinguish it for the present purpose as coast water.

4. Water from 30 to 32 per thousand salinity, or less, belonging to the outflowing stream from the Baltic.

The numbers of course signify the parts of salt by weight in a thousand parts of the water.

Now, the oceanic water fills the central part of the North Sea as far as the Dogger Bank from bottom to surface. Towards the east it does not reach to the surface, but fills the bottom of the deep channel which extends along the Norwegian coast and into the Skagerack.

The North Sea water is found in the North Sea south-east and west of the Dogger Bank, and along the coasts on each side of the North Atlantic Ocean. In the Skagerack it lies over the oceanic water, and is not found at the surface, except in a band along the north coast of Denmark. The North Sea water flows into the Skagerack principally in spring and summer.

The coast water flows into the Skagerack most abundantly in autumn and winter, when it reaches a considerable thickness, and predominates at the surface in the central part of the channel. In summer time the quantity of this water present is very much reduced. It is then displaced by Baltic water.

The cause of the difference in the amount of the influx cannot be other than the periodic variation in the outflow from the Baltic. When the Baltic outflow decreases, coast water flows into the Skagerack, where it is found as a thick and relatively warm surface layer in the coldest months of the year. When the outflow of Baltic water increases in spring and summer, the coast water is swept out of the Skagerack again, and at the same time the deeper waters begin to flow in and swell in volume. Professor Pettersson attributes the latter inflow to a reaction upon the deeper strata in the North Sea, due to the energy stored up in the waters of the Baltic, but I must confess that for my comprehension these expressions require further explanation. The annual variation in the Skagerack affects the water to a depth of about 50 fathoms.

The temperature of the North Sea water varies inversely with that of the season; it is the coldest water of the Skagerack in summer, and the warmest in winter.

The North Sea water varies much in the amount of dissolved oxygen which it contains; in July, 1890, it was very deficient in oxygen, while in September, 1893, it was supersaturated with that gas, a condition which has only been found to occur in surface waters from high latitudes.

The North Sea water begins to flow into the Skagerack in May, and its entrance coincides with the commencement of the mackerel fishery on the Swedish coast. There seems to be a certain connection between the expansion of the volume of 34 per cent. water in the Skagerack, and the appearance of the mackerel and gar-fish.

The temperature of the coast water, on the other hand, and still more of the Baltic water, varies with that of the season.

The coast water may flow into the Skagerack from two directions, namely, either from the south along the coasts of Denmark and Germany, or from the north along the coast of Norway. This is important, because there are reasons for believing that the coast water has two periods of influx. The first influx occurs in August and September, and is due to the influence of westerly gales. At this time of the year warm water, whose temperature reaches 15° or 16° C., and whose salinity is 32 to 33 per cent., sets in along the north-west coast of Jutland. It fills the central part of the Cattegat from top to bottom as far to the south as a point between Trindelen and Anhalt, and then dips under the Baltic water.

In early autumn the herring fishery, with floating nets, in the Cattegat and south Skagerack, coincides with this influx of coast water. In a subsequent part of his paper, Pettersson points out that Möbius and Heincke, in their memoir on the Fishes of the Baltic, state that there are 32 species, of which specimens occur in the Western Baltic occasionally, and are not resident there. These fish are immigrants, and 18 of the species are southern forms—that is, forms whose range extends from the Mediterranean to the British Islands, but not to the Arctic Circle, while of the remaining 14 species, 10 are northern forms—that is, species which are abundant within the Arctic Circle, but do not occur in the Mediterranean. The occurrence of the southern forms in the Baltic takes place chiefly in September and October, and, therefore, coincides with the inflow of the southern coast water. The species in question are:—

Labrax lupus, the Bass; *Sciaena aquila*; *Mullus surmuletus*, the Red Mullet; *Brama Rayi*, Ray's Bream; *Thynnus vulgaris*, the Common Tunny; *Xiphias gladius*, the Sword-fish; *Trigla hirundo*, the Tub, or Latchet; *Mugil chelo*, the Grey Mullet; *Labrus maculatus*, the Spotted Wrasse; *Crenilabrus melops*; *Gadus minutus*, the Poor Cod; *Merluccius vulgaris*, the Hake; *Solea vulgaris*, the Common Sole; *Orthagoriscus mola*, the Sun-fish; *Engraulis encrasicholus*, the Anchovy; *Conger vulgaris*, the Conger; *Carcharias glaucus*; *Trygon pastinaca*.

Now, we cannot consider the herring as a southern fish. It is very improbable that herrings enter the North Sea from the English Channel: on the contrary, the evidence points the other way—namely, to the conclusion that the North Sea herrings come from the north; and the association of herrings with southern coast water is a fact which requires further examination. Pettersson does not discuss the difficulty.

In January, February, and March, the coldest season of the year, there is an influx of water of the same salinity as that previously mentioned—namely 32 to 33 per cent., but of a temperature of only 4° to 5° C., which evidently comes from the north along the Norwegian coast. In 1893 this northern coast water was entering the Skagerack in November, and it was found to contain a very characteristic Plankton, or assemblage of minute swimming forms, entirely different from that of the adjacent water of the Baltic current. The latter consisted chiefly of vegetable organisms, such as Diatoms, Ciliofiagellates, etc., intermixed with Copepods, such as *Centropages hamatus*, which occur also in the Cattegat and Baltic up to the Aland Islands, at the entrance of the Gulf of Bothnia.

In the northern coast water, on the contrary, vegetable Plankton was scarce, and the animals were of Arctic or North Atlantic origin, which never appear in the Skagerack during summer, *e.g.*:—

Euphausia inermis (Kröyer) (*Schizopod*); *Hyperoche Kröyeri* (Bovallius) (*Amphipod*); *Parathemisto oblivia* (Kröyer) (*Amphipod*); *Diphyes truncata* (M. Sars) (*Siphonophore*).

The first-mentioned is known to be the principal food of the great whale, *Balenoptera Sibbaldii,* and is most abundant between Varanger Fjord and the Lofoten Islands. The herring fishery was then going on in the neighbourhood of Lysekil. Only 33 per cent. of the herrings caught had any food in their stomachs, and it consisted of 15 forms of animal Plankton, of which the remains of *Limacina balea* was the most remarkable. This Pteropod frequents chiefly the North Atlantic and Arctic Ocean, and occasionally appears on the west coast of Norway, where it is greedily devoured by herrings. As not a single specimen of the species was found in the waters of the Skagerack in November, the shells of the *Limacina* in the stomachs of the herring must have been a remnant of the food swallowed by the fishes outside the Skagerack. The winter herring are caught in water of the kind denoted here as northern coast water, and disappear with it.

The northern species of fish mentioned by Möbius and Heincke as occurring occasionally in the Baltic are:—*Liparis Montagui,* Montague's Sucker; *Anarrhichas lupus,* the Cat-fish; *Stichaeus Islandicus*; *Gadus pollachius,* the Pollack; *Hippoglossus vulgaris,* the Halibut; *Pleuronectes cynoglossus,* the Witch; *Gadus virens,* the Coal-fish; *Lota molva,* the Ling; *Raia radiata.*

According to Pettersson these northern fishes are only found in the Western Baltic in the early part of the year, that is to say, chiefly in January, February, and March, during the time when, as he has proved, there is an inflow of coast water of a temperature of 4° to 6° C. along the south coast of Norway into the Skagerack and Cattegat.

Having analysed with so much success the composition of the waters entering and leaving the Baltic, Professor Pettersson and the Swedish hydrographers associated with him, conceived the project of extending the application of their methods to the whole of the North Sea, in order to distinguish the different waters entering and leaving that basin, and to trace them to their sources. Proposals were accordingly made to the governments of other countries bordering the North Sea, that they should take part in an international co-operative hydrographic survey. On behalf of Britain the Scottish Fishery Board undertook to survey the region to the north and east of Scotland. In accordance with the plans arranged, H.M.S. *Jackal* was employed in the work, and Mr. H. N. Dickson, F.R.S.E., was entrusted with its execution. Four expeditions to the northern entrances to the North Sea were made—in August and November, 1893, and in February and May, 1894. The results of the observations are recorded in detail in the Twelfth Report of the Scottish Fishery Board; and in *Natural Science* for January, 1895, Mr. Dickson published an article in which he discussed the probable influence of the movements of water which had been ascertained to occur, on the migrations and distribution of fishes, and consequently on fisheries.

Mr. Dickson regards the subject in a manner which seems to me peculiar; and while his work in the physical department is well known to be in all respects admirable and sound, I am obliged to express some disagreement with the argument he employs concerning the biological questions. He urges that we cannot discover direct hard and fast relations between the temperature or the salinity or the density of sea-water, and the constant or periodic occurrence of certain animals (*e.g.*, fishes) in particular localities. Yet we have to discover some reason for the fact that the appearance of certain fishes and other marine animals has been frequently observed to be associated with a periodical change in the temperature or salinity of the water. Mr. Dickson says that the peculiarities of temperature or salinity are certainly too slight to seriously affect animal life. But he points out that it is just these two physical elements upon which the oceanographer relies in tracing the circulation of waters, and in identifying the sources from which they are derived.

He proceeds to lay stress upon the alleged fact that Pettersson and his colleagues have collected a mass of evidence shewing that the migrations of herring and mackerel, and other variations in the distribution of not only fishes, but Plankton, are dependent on the amount of oxygen present in the sea-water. The amount of oxygen dissolved in the water depends solely on the temperature and atmospheric pressure to which it was exposed when at the surface. The lower layers of water, in enclosed areas, are accordingly liable to become deficient in oxygen, and fresh supplies must be obtained by mixture with water from the ocean, if animal life is to remain healthy and abundant.

Now, after careful study of Pettersson's papers in the *Scottish Geographical Magazine*, I cannot perceive that they exactly correspond to Mr. Dickson's description. According to Pettersson, the advent of the mackerel corresponds to the influx of North Sea water in May and the following summer period. During winter the amount of North Sea water present in the Skagerack decreases, and that which remains becomes deficient in oxygen. But it is scarcely possible to hold that the deficiency of oxygen in this layer of water alone causes the mackerel to leave. For in the first place mackerel swim very near the surface, and are therefore not, in all probability, contained in the North Sea water at all, but in the overlying Baltic water, which in summer flows out through the Skagerack in considerable quantity. Then, again, the herring enter the Skagerack, according to Pettersson, in autumn and winter, with the influx of coast-water from the north.

If it were a mere question of oxygen, there would be no reason why the mackerel should migrate to the Swedish coast in summer, and the herring in winter. Moreover, the coast-water flows in at the surface, and displaces the Baltic current in winter, and so far from being richer in oxygen, contains less of that element than the surface water of the Baltic. In a foot-note on the latter, Pettersson states:—

"This singular fact that the waters of the Baltic upper layers may occasionally be supersaturated with oxygen like Arctic water, is worthy of attention. I have discussed this phenomenon with the eminent specialist on diatoms, Professor Cleve of Upsala. We both arrived at the conclusion that supersaturation with oxygen, as well as deficiency of oxygen, is probably due to the influence of organic life. The predominance of vegetable Plankton, which is characteristic of Arctic as well as of Baltic water, may cause the former, the respiration of animals and of animal Plankton the latter phenomenon.

"Be this as it may, it is certainly a fact to be borne in mind by biologists, that the conditions of organic life are very different in the Baltic and in the North Sea, on account of the relatively high amount of dissolved oxygen in the upper layers of the Baltic. Owing to the low salinity, the perfect aeration of the water down to a considerable depth, and the low temperature at which their water is saturated with air in winter, the upper layers of the Baltic contain about 30 per cent. more oxygen than the waters of the North Sea."

In view of the above statement, it can scarcely be maintained that the visits of migratory fish, like herring and mackerel, to the mouth of the Baltic, are to be attributed to the abundance of oxygen present in the sea-water which flows into the entrance of that sea at certain seasons of the year.

What Pettersson does prove with regard to the herring is, that its presence on the west coast of Sweden depends on the presence of water having certain qualities, and derived from a certain source. In the fifth of his series of papers, in the *Scottish Geographical Journal* for 1894, there is a special discussion of the changes in the water on the west coast of Sweden, and their effect upon the herring fishery. In 1877, after an absence of seventy years, herring again appeared on the Swedish coast. It appears to be a historical fact that, time after time, herring have entirely deserted this coast, have remained absent for a period of about seventy years, and have then resumed their annual migration to the region, giving rise to a valuable and important fishery. The cause of this regular irregularity does not concern us here, nor is it discussed by Pettersson; we are considering merely Pettersson's conclusions concerning the changes in the water which determine the arrival and departure of the herring on the coast during the period when it pays its annual visit. In the middle of December, 1878, before the herring had appeared, the salt-water of 34 per cent. salinity (North Sea water) reached to within fifteen or twenty fathoms of the surface, and filled the deep channels of the coast. The surface water overlying this consisted of layers of 32 and 33 per cent. salinity, evidently the remnant from the inflow of coast-water in autumn; the temperature of this was 8° to 9° C.

In the latter part of December stormy weather occurred, and a new influx of coast water took place, of the same salinity, but with a temperature of only 4° to 6° C. The last influx of this water occurred on the 28th and 29th December, and simultaneously the herring fishery began on the coast to the east of Wäderö Islands. In the middle of January the fishery began to decline at the same place, the cause of which was as follows: On the 11th and 12th January the wind, which had been blowing from the N.E., began to blow from S. and S.E., in consequence the fresher and colder water belonging to the Baltic stream began to flow northwards along the Swedish coast, and as the Baltic water displaced the coast water the herring disappeared. There can be no suggestion here of a superiority in the supply of oxygen in the coast water. Both the water with which the herring came, and that which drove them away, were surface waters, and both well supplied with oxygen, especially the latter. The difference between the two consisted chiefly of salinity and temperature, and the effect upon the fish may have been due rather to the movement of the water than to its qualities.

On the other hand, it is perfectly correct that Pettersson has discussed in considerable detail the absence of oxygen in the bottom water contained in deep depressions separated by higher ground from similar depths in the neighbourhood. In such cases the water contained in the depression is salter, and therefore heavier than the overlying water, and remains undisturbed and unaffected by the movements of the lighter and fresher water passing over it. When deprived of the dissolved oxygen which it contains, the bottom water, being cut off from contact with the air, can obtain no new supplies, except what it takes up by diffusion from the layers of water above it, and that is scarcely any. The oxygen originally contained in it is constantly being abstracted by the respiration of the animals that live in it, and by algae also in the absence of light, so that if undisturbed for a long time water in an isolated depression becomes almost entirely destitute of oxygen, and, therefore, incapable of supporting animal life. Pettersson states that these are the conditions to which the deep basins of the fjords on the west coast of Sweden are subjected, because the bottom of the fjords is much higher and nearer the surface of the water at the entrances than at the inner parts, so that below a certain depth the water in the fjords is cut off from communication with the water in the open sea. The Gullmar Fjord is described as a typical example. The depth of water on the Swedish coast bank, *i.e.*, from the shore of the mainland as far as the outermost rocks and shoals, does not usually exceed 15 fathoms. But corresponding to each fjord, leading from its entrance towards the S.W. there is a deeper channel, cut off from the deep inner basin of the fjord by the ridge across its mouth.

In summer the ocean water and the North Sea water in the Skagerack extend from the bottom nearer to the surface than in winter, and above the North Sea water lies the Baltic water, which flows out most abundantly in summer. On the declivity of the coast the layer of Baltic or fresh water is deeper than in the central part of the Skagerack. In consequence of these facts the ocean water never enters the Gullmar Fjord, because its level never reaches to within 20 fathoms of the surface on the coast declivity, and that is the depth of the ridge at the entrance of the fjord. The North Sea water, however, whose salinity is 34 per 1000, enters the fjord occasionally, or periodically, and it is water of this salinity which fills the inner basin of the fjord. Waters of 33 per 1000 and less flow into or out of the fjord from the surface to the depth of 20 fathoms at all seasons of the year.

It was found that the bottom water of the Gullmar Fjord in February, 1890, was extremely deficient in oxygen, that it was cut off from communication with water of the same salinity outside, which contained plenty of oxygen. In June, 1890, the level of the North Sea water outside the fjord rose to less than 20 fathoms from the surface, flowed over the ridge, and displaced or mixed with the stagnant water already there. This did not happen again until 1893.

The Gullmar Fjord is noted for the fishery for cod and John Dory in its deep water, a fishery which takes place in winter, but not every winter. In the winter of 1889–90 this fishing was very poor, and had been so for some previous years. In the winter of 1890–91 it was very successful. The inference suggested is that the entrance of these fish into the Gullmar Fjord is dependent upon the entrance of North Sea water in summer, which does not always occur. When it does not occur, even if the fish should enter the fjord by swimming over the bar at the entrance, the bottom water of the fjord would be nearly or quite uninhabitable for them on account of the small supply of oxygen it contains. Pettersson expressly points out that he does not consider the herring fishery in the fjord to be affected by this change in the bottom water, but believes it to be dependent upon the inflow of coast water at the surface, in the manner which has already been described.

The general results of Mr. Dickson's own investigations of the conditions and movements of the sea-water to the north of Scotland were as follows. Between the Faröe and Shetland Islands and the submarine elevations of which they are the highest points, is a narrow submarine valley extending from the deep basin of the Norwegian Sea. This valley is separated at its south-western end from the deep basin of the Atlantic by the Wyville Thomson ridge, which is only 300 fathoms from the surface of the sea. Over this ridge the water of the Atlantic flows throughout the year towards the north-east, its movement being caused by the cyclonic winds in winter and by the greater warmth and consequent higher level of the Atlantic water in summer as compared with the Norwegian Sea. The Atlantic water flowing over the ridge sucks up the cold water from beneath, and mixes with it. Owing to its greater saltness the Atlantic water thus cooled sinks and loses its velocity. The influence of the earth's rotation deflects the current to the right, and thus in summer a mass of Atlantic water tends to collect on the north-western and northern edge of the North Sea bank. At all seasons this water enters with the tides between the Orkneys and Shetlands, but in winter, westerly winds drive it towards the east, and none passes down the east coast of Britain. But in summer, when the winds are light, and the surface layers of the North Sea are warmer and lighter, the Atlantic water mixes with the cold bottom water of the North Sea, and finds its way along the east coast of Scotland. The causes by which, according to Mr. Dickson's explanation, this is accomplished, I do not profess to fully understand. The explanation given is that the Atlantic water collected at the edge of the North Sea bank mixes with the cold bottom water already there, and increases its salinity but reduces its specific gravity by warming it. At a certain stage of mixture the temperature and salinities of the two waters combine to form an axis of maximum specific gravity. This axis, which probably runs N.E. from Shetland at the end of May or in June, turns slowly toward a N. to S. direction and moves eastward. As it retreats, Atlantic water is gradually admitted round the north end of the Shetlands, passes down the east side of the islands, joins the tidal stream at the south end, and guided by the axis of heavy water, is distributed along the east coast of Scotland probably during July and August.

In his essay in *Natural Science*, Dickson states that it is in the oceanic or Atlantic water, thus admitted in summer down the east coast of Scotland, that the summer and autumn herring fishery takes place, and remarks that whether this fresh supply of oceanic water really does contain a markedly greater amount of oxygen than the water it replaces can only be ascertained by actual analysis (which was not carried out), and that the further question, whether the herring comes with this water or to it, must be settled by zoologists.

In his paper on "The Movements of the Surface Waters of the North Sea," published in the *Geographical Journal* for March, 1896, Mr. Dickson tells us that in the International Hydrographic Survey, in 1893 and 1894, Denmark, Sweden, Germany, Scotland, and Norway took part. The plan was to obtain simultaneous observations in different parts at times arranged beforehand. In May, 1893, Danish and Swedish ships were at work; in August and November, 1893, and February and May, 1894, ships from the Kiel Commission and the Fishery Board for Scotland co-operated; while a Norwegian vessel also made observations in the latter periods. Mr. Dickson gives a summary of all the observations so far as they refer to the surface waters, combining with them observations made on merchant vessels, obtained from Professor Pettersson and from the Meteorological Office in London.

In his preliminary remarks Mr. Dickson points out a fact which, obvious enough in itself, is of great importance, namely, that the original sources of the water in the North Sea are the oceanic waters entering from the north and north-west, and, to some extent also, from the Straits of Dover, and land waters entering from the Baltic and the rivers. The other waters, distinguished and appropriately named by Pettersson, are due to mixture of these two. In a large and deep basin the fresher water would overlie the ocean water, and mixture would take place slowly; but in a shallow basin like the North Sea the influences of wind and tide penetrate to the bottom, and mixture sometimes takes place with great vigour and rapidity, so that North Sea water (34 to 35 per thousand) sometimes occupies almost the entire basin. The varying temperatures of the seasons and the force of winds are very important local influences governing the distribution of the different waters.

Descriptions are then given of the distribution of the various waters as distinguished by Pettersson in May, August, and November, 1893, and in February and May, 1894. The distribution is well shown on the series of coloured maps, one showing the salinities, the other the temperatures of the surface waters. Perhaps the most important point to notice at the different periods is the distribution of oceanic water, which enters from the north southwards, and from the Straits of Dover northwards, but the temperatures are also, in relation to the distribution of fishes and other animals, of great importance.

At the beginning of May, 1893, oceanic water covers a small area well to the north and north-east, forming a central tongue terminating opposite the entrance of the Baltic, and an isolated patch between East Anglia and the Dutch coast. The rest of the North Sea is covered by North Sea water, except a narrow edging along the continental coast extending some distance into the Skagerack; this is coast water. The isothermals, or lines of equal temperature of the surface water, are interesting at this period. At the western entrance of the English Channel we have 12° C., which diminishes as we pass up the Channel, but the limit of 9° C. passes from the islands outside the Zuyder Zee to a point on the English coast about Flamborough Head. North of this we have only 8° and then 7°, a band of the latter extending from about Aberdeen to the Baltic and along the Norwegian coast, while north-west of this we have again 8° and 9°. Along the whole of the western coast of the British Islands, the Atlantic temperature is 9° and 10°. The influence of this distribution of temperature alone, on the distribution of southern species of animals, cannot, I think, be over-rated, as will be seen below when the distribution of animals is considered. The distribution of animals is not discussed at all by Dickson in the paper with which we are now dealing.

In August, 1893, the northern tongue of oceanic water is broader and extends further southward, reaching to the edge of the Dogger Bank, while in the south a tongue from the Straits of Dover extends to the latitude of Lowestoft. The band of coast water along the German and Danish coasts is somewhat broader, but it does not extend into the Skagerack; we now see the Baltic current or stream flowing out in full force, extending northwards along the Norwegian coast in a broad band. This Baltic water is now, owing the influence of the sun on the land, of higher temperature than any other part of the surface of the North Sea, except two isolated patches near the British coasts. The whole of the North Sea (surface) is now as warm as the Atlantic water on the west coasts of the British Islands. Both in the North Sea and on the west coasts, the temperatures diminish from south to north from 18° to 13° C., but a narrow tongue of colder temperature extends southward, so as to include the Orkney and Shetland Islands and part of the Moray Firth.

In November, 1893, the northern tongue of oceanic water is broader, but does not extend further south; the southern tongue extends a little beyond the Texel. The outflow of the Baltic stream has ceased, and coast water is seen in the map extending along the south-west coast of Norway and entering the Skagerack, in the manner previously described by Pettersson.

The temperature of the surface water is now lowest in a band along the coast of Holland, Germany, and Denmark, corresponding closely with the extent of the coast water, where it is 8°. This same temperature extends from the coast of Norway to the east coast of Scotland, and the Orkneys and Shetlands. The rest of the North Sea is 9° and 10° C., becoming warmer towards the English Channel, at the western entrance of which we have 11° to 13°. On the west coasts of the British Islands the temperature is 9° and 10°, as in the south-western part of the North Sea. Mr. Dickson observes that the low temperature on the east coast of Scotland at this period corresponds to the up-welling of bottom water which has been observed there.

In February, 1894, we find that the northern and southern tongues of oceanic water have met and joined, so that there is a broad central region of this water extending completely through the North Sea. North Sea water occupies a narrow strip on each side, and extends in a narrow tongue into the Skagerack. Coast water is seen on the south coast of Norway, extending into the Skagerack as far as the Skaw, and as usual in a narrow band along the east coast of the North Sea.

Surface temperature is now at its lowest for the year. From the east coast of the North Sea nearly to the middle it is only 4° C., this temperature extending all over the Heligoland Bight. Over the whole of the western part of the North Sea the temperature is only 5° and 6° C. On the west coast of the British Islands we have temperatures of 7° and 8°, including the western entrance of the English Channel, but 9° and 10° are found not far to the westward in the Atlantic.

The yearly cycle has now been completed, but we have also observations and charts for May, 1894, and these show that the conditions of May, 1893, are not exactly repeated. It would naturally be expected that the same conditions do not recur exactly at the same period every year, if ever, though there must be a general similarity in successive years. In May, 1894, the data are incomplete, but they show that oceanic water extended throughout the central part of the North Sea, as in the preceding February, with a narrow band of North Sea water on each side. The temperatures are more similar to those of May, 1893, but are rather higher, that of 8° C. extending over nearly the whole of the northern part of the North Sea, while, as in the earlier period, the temperature of 9° extends on the west coast of our islands beyond the north of Scotland.

Professor Pettersson has also mapped the distribution of surface salinity over the greater part of the North Sea at the end of November, 1894, and the middle of February, 1895. In November, 1894, the total area occupied by oceanic water was but small, and the Baltic outflow, instead of being cut off, as at this time in 1893, extended far to the northward. Absence of winds may account for the weakness of the oceanic streams, and the greater strength of the Baltic stream is ascribed to the mildness of the season.

Mr. Dickson adds a discussion of the forces at work in producing the observed conditions and changes, taking separately the local forces in the North Sea and the external. He finds that the chief influence at work locally is the wind. His conclusions are that the existence of a continuous strip of oceanic water along the central axis of the North Sea, is due to westerly and south-westerly winds strengthening the oceanic current. Strong northerly winds tend to broaden the northern area of oceanic water, and to blunt its extremity, and also have the effect of sending coast water southwards along the west coast of Norway: it is probable that this is the cause of the inflow of coast water into the Skagerack. Calm weather favours the spread of North Sea water over a great part of the North Sea, while easterly and south-easterly winds spread the fresher waters of the east side of the sea over the surface.

With regard to the inflowing or oceanic waters, as they are all of about the same salinity, Mr. Dickson infers their movements from the different temperatures. He finds that the Atlantic streams are on the whole strongest in summer, but the cold streams moving southwards from the eastern coasts of Iceland and Greenland are also strongest in summer. It is a mixture of the two which takes place in the Faröe-Shetland Channel, and this mixture is driven into the North Sea in the manner already mentioned.

I do not think that, for my present purpose, it would be of much advantage to give a more detailed account of Mr. Dickson's discussion of the physical conditions. He does not enter upon their relation to the migrations and distribution of fish, and it seems to me that, with respect to this relation, the changes and distribution of actual temperature and salinity in detail are of more importance than the forces by which these changes are caused. The points of view of the physicist and the biologist are different. The former is chiefly interested in tracing the causes of the observed movements of waters, regarding temperature and salinity rather as qualities by which the different currents are to be identified. The biologist's business, on the other hand, is to ascertain how the degrees of temperature and salinity affect the migrations and distribution of different species of fish. It must be understood, therefore, that in this paper I have, to a large extent, expressed conclusions of my own concerning the relation of the observations published by the physicists to those made by zoologists.

We have then to consider more particularly what is known concerning the actual distribution of fishes and other animals in the North Sea, and the waters communicating with it. With regard to two well-defined portions of the regions, namely, the Baltic and the Heligoland Bight, the facts have been collected and analysed in a very interesting manner by the German naturalists associated with the Kiel Commission, and the

Biological Station on Heligoland. The fish of the Baltic have been considered by Möbius and Heincke in a paper* which has already been cited, while Fr. Heincke alone has treated the fishes of the Heligoland Bight in a similar manner.† Papers on the other animals of these districts are also contained in the publications of the same institutions. For the rest of the region I have to rely on various ichthyological works, and on my own experience.

The peculiarity in the general distribution of fishes in the North Sea is that southern species are found along its eastern side, and at its northern as well as its southern entrance, but are absent on its western shores, and in its central and western portion. The reason of this, as Heincke points out, is that there are two routes by which southern species can enter the North Sea, namely, that of the Gulf Stream—the drift of Atlantic surface water which bathes all the western coasts of the British Isles, flows past the Shetlands to the coast of Norway, and sends a twig into the Baltic; and secondly, the route which leads from the English Channel, a slow stream of southern warmer water passing along the Dutch and other continental coasts.

SOUTHERN SPECIES ENTERING THE NORTH SEA FROM THE SOUTH.

In discussing distribution it is necessary to distinguish between littoral species, which inhabit the zone of sea-weeds, surface species, which feed and swim in the open water, and bottom species, which feed on the bottom; Heincke uses for the latter two divisions the terms aperticolous and fundicolous. He also distinguishes three divisions according to the frequency of their occurrence, namely, common resident species, rarer resident species, and occasional immigrants. We do not know with sufficient completeness the seasonal movements of the majority of fishes in a particular locality, but there is evidence to show that the aperticolous species are most migratory, the fundicolous less so, and the littoral species least of all. It is fairly certain that aperticolous southern species enter the North Sea from the Straits of Dover only in summer, and that they retire in winter. The aperticolous southern forms found in the Heligoland Bight are *Scomber scomber*, the Mackerel; *Caranx trachurus*, the Scad; *Belone vulgaris*, the Gar-fish; *Merluccius vulgaris*, the Hake; *Thynnus vulgaris*, the Tunny; *Engraulis encrasicholus*, the Anchovy.

* Fische der Ostsee. *Vierter Bericht der Commission zur Untersuchung der deutschen Meere*, 1883.

† *Wissenschaftliche Meeresuntersuchungen herausgegeben von der Kommission zur Untersuchung der deutschen Meere, und der Biologischen Anstalt auf Helgoland, Neue Folge, Erste Band, Heft* 1, 1894.

Heincke places the mackerel among the common resident forms, and in general only considers the comparative abundance and rarity of the forms, while I am endeavouring to trace the relation between the temporary and permanent presence of certain species on the one hand, and temporary and permanent physical conditions on the other. The anchovy, according to Heincke, has not been yet found at Heligoland, but we know that it is abundant in summer in the Zuyder Zee, and Ehrenbaum found its pelagic ova further to the east near the Island of Nordeney.

We must remember that these forms might reach the Heligoland Bight from the north, since all of them occur in the Skagerack and Western Baltic. It is probable that the hake does come from this direction, as it is a deep-water fish, and has scarcely ever been taken in the shallow part of the North Sea south of the Texel; it is not mentioned in Van Beneden's "Fishes of the Coast of Belgium."* It is not common in the Heligoland Bight, being placed by Heincke among the rarer residents. The tunny is still more rare, and is classed by Heincke as an occasional visitor. It probably comes both from the south and the north, as it has been occasionally taken on the coast of Kent and of Norfolk. But on the whole, as it is an oceanic fish, it is more likely to reach Heligoland from the north. The other four species are more important, because they visit the region in question in greater numbers, and they undoubtedly come from the south through the Straits of Dover, appearing regularly every summer in the narrow southern part of the North Sea between the coasts of Holland and Belgium and the English coasts, as well as on the south coast of England. The anchovy, however, is practically absent from the English side north of Kent.

All these four species are so scarce as to be practically absent along the east coast of England, but become somewhat more abundant towards the north along the east coast of Scotland, owing clearly to their incursion from the north.

Although more complete observations are required concerning the time at which these fish are present in the southern and eastern part of the North Sea, we have evidence that they occur there only in summer and autumn, and disappear in winter. Mackerel fishing at Lowestoft begins at the beginning of May, and lasts till the end of June, and there is a second or autumn fishery in September and October. It is difficult to understand why these fish are not present in the same neighbourhood in July and August. Van Beneden states that the scad appears regularly on the coast of Belgium towards the end of April, before the arrival of the mackerel. The gar-fish occurs

* *Mémoires de l'Acad. Roy. de Belgique.* Tom. *XXXVIII.*

at the same time as the mackerel: in the Schelde it is taken with the anchovies in May and June; I have seen it at Brightlingsea in the same two months, and I also saw several specimens brought in with the mackerel at Lowestoft on October 12. The saury-pike (*Scombresox saurus*) has habits similar to the gar-pike, but occurs only occasionally, apparently not every year. Van Beneden states that he saw a shoal swim ashore near Ostend. The anchovy fishery in the Zuyder Zee and the Schelde takes place principally in June and July, although young specimens are found there for some time afterwards. They appear to depart entirely before the end of October.

There can be little doubt, I think, that the annual incursion of these migratory fishes into the North Sea along the continental coast depends primarily on temperature. In the regions we are considering the depth is less than 20 fathoms, and there can be little question of difference between bottom and surface temperature. In February, which is the month in which the water is coldest, as we have seen the west side of the North Sea is at 6°, the east side, east of the Texel, 4° to 5°. We may consider that this is cold enough to drive out mackerel and the other species mentioned. At this time the limit of 9° C. lies to the west of the western entrance of the Channel. Mackerel in January and February are caught in the western part of the Channel as far east as Start Point. In May the limit of 8° has advanced eastwards and runs across the North Sea from the southern part of Denmark to the Firth of Forth. In August temperatures above 13° prevail over the whole of the North Sea, and in November we find the cold again advancing from north to south and from east to west.

These surface temperatures do not, however, explain the absence of the fish in question from the coast of Britain in summer. The restriction of the fish to the continental coast may be due to two causes: firstly, a movement of water in that direction; secondly, the extension of the deeper portion of the North Sea along the east coast of Britain. The salinity of the water has little to do with the matter. We have seen that in 1894 the oceanic water was more extended in February than at any other time of the year. Concerning the question of an inflow of water from the Straits of Dover, this distribution of surface salinities does not indicate that it is greater in summer than in winter. The report of an expedition for physical investigation, to which no reference has yet been made, namely, that of the *Pomerania* in 1872, does mention that the outflow of the warmer water from the southern area of the North Sea was traced as a current which flowed along the coasts of Schleswig-Holstein and Jutland to the Skagerack. This was in summer, but it seems to me that the surface salinities indicate that this current is due rather to the greater outflow of fresh water from the continental rivers, than to a greater flow of salt water from the Straits of Dover. At any rate, so far as I understand it, the physical evidence does not show that there is an inflow of Channel or Atlantic water corresponding to the immigration of southern aperticolous fish, while the higher temperature which does correspond to that immigration appears to be caused by the warming of the land and shallow water by the summer sun.

On the other hand, the *Pomerania* observations actually prove that in the deeper north-western depression the bottom water was frequently below 8° C., and that the passage of this cold water southwards was arrested by the Dogger Bank. I think it would be more correct to say that the boundary of this cold water to the south and east is the 25 fathom line. It is reasonable to infer that although the temperature at the actual surface in summer on the north-east coast of England is by no means low enough to account for the absence of mackerel, anchovy, etc., yet the influence of the cold water below is sufficient to restrict these southern species to the region south and east of the 25 fathom line.

We proceed next to the consideration of the southern species of fundicolous or bottom fishes in the Heligoland Bight and southern area of the North Sea. The list of these is rather a long one. The commonest of them are: *Rhombus maximus,* the Turbot; *Rhombus laevis,* the Brill; *Solea vulgaris,* the Sole; *Solea lutea,* the Solenette; *Trigla gurnardus,* the Grey Gurnard; *Trachinus draco,* the Greater Weever; *Trachinus vipera,* the Lesser Weever.

Less abundant are: *Trigla hirundo,* the Tub or Latchet; *Trigla cuculus,* the Red Gurnard; *Mullus barbatus,* the Red Mullet; *Callionymus lyra,* the Dragonet; *Arnoglossus laterna,* the Scaldfish; *Galeus vulgaris,* the Tope.

Heincke does not mention *Trachinus vipera* among the fishes of Heligoland. In the voyage of the *John Bull* off Amrum in June, I saw nothing of either species of weever, but both were very common on the Brown Ridges off the Dutch coast in September.

Heincke believes *Trigla cuculus* to be absent, but I saw specimens, identified with certainty, taken frequently in the trawl in my voyages both north of Heligoland and on the Brown Ridges.

As occasional immigrants the following species occur: *Labrax lupus,* the Bass; *Zeus faber,* the John Dory: *Gadus luscus,* the Pout or Bib; *Motella tricirrata,* the Three-Bearded Rockling; *Conger vulgaris,* the Conger; *Mustelus vulgaris,* the Smooth Hound; *Scyllium canicula,* the Small Spotted Dog-fish; *Trygon pastinaca,* the Sting Ray.

To the fundicolous forms may be added *Amphioxus lanceolatus,* which burrows in the sea-bottom, and is common near the Horn Reef.

How far the movements of these fundicolous species are influenced by the seasons we have very little evidence to show.

I think that it will be found that the occasional immigrants are usually taken in the area in summer, *i.e.*, during the period when the water is warm. I obtained a specimen of *Mustelus vulgaris* off Lowestoft on September 18th. The grey gurnard is not such a distinctly southern form as the latchet, nor is the red, *Trigla cuculus*. On board the steam-trawler *Lucania*, to the south of the Horn Reef in May, no latchets were taken, while northern forms, such as haddock, were abundant, and one halibut was taken. Grey gurnard were plentiful. Latchets were plentiful off Amrum in June, and on the Brown Ridges in September.

It will be found that the abundance of these forms in the Heligoland Bight is in proportion to the degree of their restriction to a southern habitat. The turbot, brill, and sole are fairly common along the north-east coast of England, while turbot and brill extend along the east coast of Scotland, accompanied by *Trigla cuculus*. As for the weevers, I do not think they are rightly said by Heincke to be common in the neighbourhood of Heligoland, as I did not meet with them there, nor at Grimsby, and although McIntosh records them as not uncommon at St. Andrew's, this may mean merely that a few specimens are seen every year. They were certainly abundant on the Brown Ridges in September.

It is well known that in hard winters soles are caught by the trawlers principally in the deeper depressions in the North Sea, especially in the Great Silver Pit south of the Dogger Bank. The latter is an isolated depression, and being cut off from the influence of the water in the deep valley along the north-east coast of Britain, probably contains warmer water than that valley in winter. The physical condition of such depressions in winter does not appear to have been examined, but the fact that soles collect in the Great Silver Pit in winter indicates that the species we are considering are affected by the fall in the temperature of the shallow eastern and southern waters in the coldest months of the year. At present I have no further knowledge of the relative abundance of the southern fundicolous species in the southern area and the Heligoland Bight from December to April.

The third class of southern species in the same region comprises the littoral species, which live principally among the sea-weeds of the littoral zones, and belong chiefly to the families of wrasses, pipe-fishes, gobies, etc. The commonest of these at Heligoland are: *Gobius minutus*, the Sand Goby; *Nerophis aequoreus*, the Snake Pipe-fish; *Ctenolabrus rupestris*, the Goldsinny. Less abundant are: *Syngnathus acus*, the

Common Pipe-fish; *Siphonostoma typhle*, the Broad-nosed Pipe-fish; and still rarer, *Labrus mixtus*, the Striped Wrasse. To these may be added *Mugil chelo*, the Thick-lipped Grey Mullet, which haunts the shore, but is an active wandering fish, not restricted in its movements like the others.

Heincke does not mention *Labrus maculatus*, the Spotted Wrasse, which, having a much more extended range than *Labrus mixtus*, is more likely to occur at Heligoland than the latter. Possibly this is a mistake, and *maculatus* should be substituted for *mixtus* in the above list. *Labrus maculatus* has certainly been taken at Yarmouth and Lowestoft, and occurs all along the east coast of Britain, while *mixtus* has scarcely ever been taken there.

It is not likely that any of these species, except the grey mullet, make long journeys at different seasons; they are in all probability resident where they are found in the region considered. They are southern species, which are able to bear the winter cold: Heincke states that they are driven in the cold months of the year from the inter-tidal zone into somewhat deeper water.

My conclusions concerning southern species entering the North Sea from the south, are as follows:—

(1) The area in which the more characteristic southern species, such as mackerel and *Trigla hirundo* are found, is bounded by a line drawn from the north coast of Norfolk in a north-easterly direction to the 20 fathom line, and following the latter limit to the Horn Reef.

(2) Certain southern aperticolous species visit this area only in summer, from May to October, and certain fundicolous species are found there at the same time, but how far the latter are absent in winter is not known.

(3) The immigration of these southern forms at this period of the year appears to be determined by the higher temperature due to the season, not by an inflow of water taking place only at that season. The uniform shallowness of the water is, however, an important factor, on the one hand causing a great difference between summer and winter temperatures, and, on the other, protecting the area in summer from the influence of the cold water in the deeper part of the North Sea, to the north and west.

Southern Species Entering at the North.

We next proceed to study the distribution and migrations of southern species in the northern part of the North Sea. In a previous part of this paper, I have already given a list of 18 species of southern forms, which according to Möbius and Heincke are occasionally taken in the

Western Baltic. But it will be more instructive now to take the species of the southern area in the divisions already distinguished, and note which occur in the Western Baltic and which do not, and what others occur in addition. This analysis has been made by Heincke. Of the aperticolous southern species of the southern area of the North Sea, all occur also in the Western Baltic. The mackerel, scad, and gar-fish occur in some numbers, and are classed by Möbius and Heincke as constant rarer residents, but are really summer immigrants making their appearance in May, and absent after October or November. The hake is a rare visitor, and has only been occasionally taken on the east coast of Schleswig-Holstein in November and December. The tunny and anchovy are also but occasional immigrants, which have been occasionally taken in autumn.

Of fundicolous forms, the following, according to Heincke, do not occur in the Western Baltic: *Zeus faber*, the Dory; *Callionymus lyra*, the Dragonet; *Gadus luscus*, the Pout; *Motella tricirrata*, the Three-bearded Rockling: *Solea lutea*, the Solenette; *Arnoglossus laterna*, the Scald-fish; *Galeus vulgaris*, the Tope; *Mustelus vulgaris*, the Smooth Hound; *Scyllium canicula*, the Small Spotted Dog-fish; *Amphioxus lanceolatus*, the Lancelet.

All these species have, however, been found in more or less abundance on the west and south coasts of Norway, with the exception of two, *Solea lutea*, and *Mustelus vulgaris*. The latter has been taken at the Shetlands and Orkneys. Of littoral species only two, *Nerophis aequoreus* and *Labrus mixtus*, are stated by Heincke to occur at Heligoland and not in the Western Baltic, but these again are fairly common on the south and west coasts of Norway, as far to the north as Tromsö.

On the other hand, the following southern species occur in the Western Baltic, which are not found in the Heligoland Bight or the southern part of the North Sea:—

APERTICOLOUS: *Sciaena aquila; Xiphias gladius; Orthagoriscus mola; Carcharias glaucus.*

FUNDICOLOUS: *Brama Rayi* (deep sea); *Gadus minutus; Raja fullonica.*

LITTORAL: *Gobius niger; Labrus maculatus; Crenilabrus melops; Nerophis ophidion.*

In addition to these a large number of southern species have been taken more or less frequently on the west coast of Norway. Of pelagic or aperticolous forms, Collett (*Norges Fiske*, 1875) gives *Lampris luna; Antennarius marmoratus; Argyropelecus Olfersii; Exocoetus volitans; Alopecias vulpes; Scopelus caninianus; Scombresox saurus.*

These southern aperticolous forms found on the coast of Norway, and not in the southern part of the North Sea, are oceanic species which live in the warmer parts of the Atlantic far from the coasts. The warm surface drift of the Gulf Stream carries them occasionally to the south-west coast of Norway, as also to the west coasts of the British Islands, but they do not penetrate through the English Channel and are, therefore, not seen in the southern part of the North Sea. They appear to be usually taken on the Norwegian coast in summer.

Certain deep-sea species extend from the Mediterranean to the coast of Norway, such as *Argentina sphyraena*, but most of these have a very wide range, and need not be considered in relation to the present subject.

The southern character of the fish found on the south-west coast of Norway is strikingly exhibited by the numerous species of *Scombridae*, *Percidae*, *Sparidae*, and *Labridae*, which are found there. Besides those which have been mentioned as occurring in the Western Baltic, we have of shallow-water forms:—*Pagellus centrodontus; Cantharus lineatus; Polyprion cernium; Acantholabrus exoletus; Acantholabrus couchii; Pristiurus melanostomus; Spinax niger* (deep sea); *Lamna cornubica: Nerophis lumbriciformis.*

In considering the relation of the occurrence of these southern forms on the south-west coast of Norway to physical conditions, we have to remember that a narrow channel over 200 fathoms in depth runs along that coast at no great distance from the shore, and that even the 100 fathom line does not go further north than the latitude of the north coast of Scotland. The warm Gulf Stream is only a surface layer, and beneath it is colder water. A large number of the southern species have only been occasionally taken on the Norwegian coast, and then chiefly in summer and autumn. They are probably to be regarded as isolated stragglers, which have been partly tempted onwards by the warmth of the water, partly carried by the surface drift. More detailed information concerning the permanence or periodicity of the occurrence of these species on this coast is required. The information available in Smith's recent edition of Fries and Ekström's *Scandinavian Fishes*, I have not yet had time to study thoroughly, as it is only given in separate statements under each species. It would appear, however, that a considerable number of littoral southern species are resident all the year, and it is to be noted that the surface temperature on the coast of Norway, to the north of 60° N. L., does not fall in February below 6°, while in the Heligoland Bight it is between 4° and 5° C. in that month.

It has been shown by the physical observations previously reviewed that in summer a strong surface outflow from the Baltic northwards along the Norwegian coast takes place, while in winter this is entirely cut off. This water flowing out in summer is at a high temperature, being warmed by the sun. It is therefore as warm as the Gulf Stream surface water from the Atlantic, and it seems to me that this fact is the chief condition determining the annual arrival of mackerel, gar-fish, scad, and anchovy on the south-west coast of Norway, and at the entrance of the Baltic.

The southern forms which have been mentioned occur also to some extent along the east coast of Scotland, but more commonly towards the north. It is therefore evident that they come round the northern end of Britain, and travel southwards. Here, again, detailed information as to the duration of their stay is at present deficient. It is stated that mackerel do not appear at the Orkneys till July, and in the Moray Firth are most abundant in August. The gar-fish, skip-jack, scad, and anchovy are all also recorded as occurring in the Moray Firth and on the east coast of Scotland, the three former as far south as St. Andrew's and the Firth of Forth. Others of the southern species which have been mentioned also are taken as isolated individuals, or in small numbers, as far south as St. Andrew's, and only in summer and autumn. *Trigla hirundo*, for instance, has been once taken at St. Andrew's, while *Pagellus centrodontus* is said to be not uncommon there. *Zeus faber*, the dory, is rare in that locality. *Labrus maculatus* occurs, and the only other wrasse is *Crenilabrus melops*, which is rare. The southern forms are scarcest or altogether absent between the Firth of Forth and the Wash.

Distribution of Northern Species.

The northern species, that is, species whose range extends beyond the Arctic circle but not into the Mediterranean, which occur in the Western Baltic, are chiefly littoral species, or fundicolous species, inhabiting moderate depths. The herring is the chief exception, being almost the only aperticolous species in the list. The species, as given by Möbius and Heincke, are: *Cottus scorpius, Cyclopterus lumpus, Centronotus gunnellus, Zoarces viviparus, Spinachia vulgaris, Gadus morrhua, Gadus aeglefinus, Gadus merlangus, Ammodytes tobianus, Pleuronectes platessa, Pleuronectes limanda, Pleuronectes microcephalus, Hippoglossoides limandoides, Clupea harengus.* Less abundant are: *Cottis bubalis, Agonus cataphractus, Liparis vulgaris, Gadus pollachius, Lota molva, Motella cimbria.* The occasional immigrants are: *Anarrhichas lupus, Gadus virens, Pleuronectes cynoglossus, Hippoglossus vulgaris, Liparis Montagui, Stichaeus islandicus (Lumpenus lampetraeformis), Brosmius brosme, Raia radiata.*

As we have seen, Pettersson points out that these northern immigrants are taken in the Baltic early in the year, from February to April, at which season the Baltic outflow has ceased, the force of the

Gulf Stream is diminished, and an influx of cold water 4° to 5° C. takes place into the Baltic, from the north along the Norwegian coast.

Five of these occasional immigrants are absent from the Heligoland region, namely, *Liparis Montagui, Stichaeus islandicus, Brosmius brosme, Pleuronectes cynoglossus,* and *Raia radiata.* These are also wanting in the southern shallower part of the North Sea, that is to say, south of the 20 fathom line, except *Liparis Montagui,* which, according to Day, occurs at the mouth of the Thames and on the south coast of England. These five are the most especially northern of the above list, and are true Arctic species. *Liparis Montagui* is common along the east coast of Scotland and north-east coast of England. Of *Stichaeus islandicus,* only one or two specimens have been taken occasionally in the north-western part of the North Sea, once in 40 fathoms off St. Abb's Head, once in February, 1894, off the mouth of the Firth of Forth, and two specimens in July, 1892, 240 miles E. ½ N. from Spurn Head. *Brosmius brosme,* the tusk or torsk, is abundant from Spitzbergen to the Shetlands, but further south becomes scarcer: it has only been occasionally taken off the Yorkshire coast. *Pleuronectes cynoglossus,* the witch, is abundant on the Great Fisher Bank, and may be said to be limited in the North Sea by the 30 fathom line. *Raia radiata* has a similar distribution, not being found south of Yorkshire.

Two species found in the Heligoland region have not been taken in the Baltic, namely, *Carelophus ascanii,* of the blenny family, and the rockling, *Motella mustela.* The former is common on the north-western coast of Norway, and occurs rarely on the east coast of Britain as far south as Yorkshire. *Motella mustela* extends southwards throughout the southern area of the North Sea, and occurs also on the south coast of England.

The other three occasional immigrants into the Western Baltic, namely, the cat-fish, the coal-fish, and the halibut, occur along the east coast of Britain as far to the south as the 30 fathom line, but not south of it.

Hippoglossoides limandoides, the long rough dab, is resident in the Baltic, and also in the north part of the North Sea, north of the 30 fathom line, but is absent from the Heligoland region, and from the shallow southern area.

The other species mentioned in the above list, although not entirely absent from the southern area and the eastern slope of the North Sea, become much scarcer there, as will be seen from the observations in these areas recorded in the two previous numbers of this Journal. The lemon dab *(Pleuronectes microcephalus)* is found more plentifully along the English coast in the southern area, *i.e.,* along the line of deeper water. *Lepidorhombus megastoma,* the megrim, is a northern form, not mentioned in the above list because not occurring in the Baltic. It is common in the northern part of the North Sea, in the deeper water, and also at Iceland, and at depths over 30 fathoms on the south-west coast of England.

In the northern region the species most abundant in individuals are haddocks, whiting, cod, plaice, dabs, lemon dabs, witches, long rough dabs, megrims, cat-fishes, ling, while on the southern ground the only northern species which are abundant are whiting, plaice, and dabs.

In this discussion I have omitted all mention of a number of species, such as *Raia clavata*, the thornback ray; *Raia batis*, the skate; *Lophius piscatorius*, the angler; which are classed by Heincke and Möbius as of indefinite distribution, because they either extend both to the Arctic Ocean and the Mediterranean, or to neither.

In the further consideration of the distribution of northern species, three subjects may be taken separately: (1) the general physical conditions, (2) the migrations of the herring, (3) the difference in the size of fish of the same species in different parts of its habitat.

(1) *The general physical conditions.* In general terms, the physical fact which determines the distribution of northern species of fish in the North Sea, is that deep water in open communication with the Arctic Ocean extends along the east coast of Britain towards the coast of Norfolk. If we look at the contour lines of the sea-bottom, we see that the 100 fathom line passes round the north of the Shetlands and bends round to the south, parallel to the Norwegian coast and at no great distance from it. The 50 fathom line passes down the east side of the Shetlands, Orkneys, and the east coast of Britain to the latitude of the Farn Islands, and runs north again along the west side of the Great Fisher Bank, to the edge of the Norwegian depression. The 40 fathom line runs further south off the east coast of England, and to the west of the Dogger Bank and Great Fisher Bank. The 30 fathom line runs outside the Dogger Bank, and the whole of the Fisher Bank is more than 30 fathoms in depth. But the 20 fathom line isolates the Dogger Bank, and leaves a valley between it and the slope of the mainland. To the south of this valley the 20 fathom line runs across the North Sea from Flamborough Head to the continental slope.

Apart from movement of the water, this depression must contain at the bottom water which is continuous with the cold bottom water of the Arctic Ocean, and which cannot be much affected or raised in temperature by the warm current of the Gulf Stream, both because that is a current of surface water, and because it flows past the north of Britain to the Norwegian coast. We see thus that the roads of the northern forms and southern forms actually cross one another to the east of the Shetlands and Orkneys, the southern species travelling in the warm surface water of the Atlantic to the south-west coast of Norway, the northern species moving at the bottom down the western side of the North Sea.

The observations of the *Pomerania* expedition previously mentioned, show that in summer, in the deep depression, the temperature at the bottom was not higher than 8° C., while at the surface it was 12° to 14° C. At the western side of the southern area the temperature at the bottom was somewhat lower than at the surface, but not on the eastern side. This is attributed to an inflow of cold water from the north. It seems to me that it is with regard to this question of the flow of the cold bottom water at different times of the year, that further information from the physicists is most required. We know that northern forms, such as haddock and lemon dabs, extend down the east coast of England as far as the Thames, in greater numbers than on the continental side, and we know that there are isolated depressions over 20 fathoms in depth along this side, which are wanting on the continental side. But it would be interesting to know further to what extent the cold water makes its way southward beyond the latitude of the Wash, and what is the cause of its movement?

Reference has already been made to Dickson's account of the entrance of oceanic water down the east coast of Britain from the north, and his opinion that the important property of this water is, that it contains more oxygen than the bottom water of the deeper part of the North Sea, which it replaces. In his interpretation of the observations, Dickson has laid chief stress on the introduction of *Atlantic* water into the west side of the North Sea at the bottom, and says little of the temperature of the introduced water. Apparently the reason of this is, that the Atlantic water was originally surface water, and was presumably saturated with oxygen. Now, the question of the oxygen in the bottom water introduced, or in that which it displaces, has not been directly investigated. It seems to me that it is very desirable that Mr. Dickson and the other physicists who are studying the phenomena in question, should consider the movements of the water in relation to the contrasted distribution of northern and southern fish, of which I have in this paper attempted to trace the main features. The herring is a northern species, abundant in the Norwegian Sea, and its incursions into the North Sea must, I think, depend, like the presence of the other northern species characteristic of the north-western part of that sea, on the introduction not of Atlantic water, but of cold water from the Norwegian Sea. It seems to me the question is one rather of temperature than of oxygen. In Dickson's conclusions it is noteworthy that the introduced water is a mixture of Atlantic water and water from the Norwegian Sea, and to me the latter constituent and its low temperature appear to be the more important factors. In any case it is important that Dickson concludes from his observations that cold bottom water does flow from the north down the north-western depression of the North Sea, and this fact corresponds to the prevalence of northern species of fish in that depression and the east coast of Britain.

(2) *The migrations of the herring.* Turning more particularly to this difficult subject, I cannot profess, with the data at present available, to give a complete explanation of these migrations. I propose merely to point out some of the more obvious relations, in the hope that my remarks may be of some use in directing attention to the conditions which have to be investigated.

On the east coast of Scotland, it appears at first sight that the summer herring arrive and are present when the water is warmest. In the northern part, for instance in the Moray Firth, the chief fishing is in July and August. Further south it gets later, taking place in August and September, while at Lowestoft it lasts from October to the beginning of December. There is a mackerel fishing at Lowestoft in September and October, so that during October, as I know from personal observation, both mackerel and herrings are being landed in numbers at the same time. But it must be remembered that the mackerel are going away to the south, and herrings are arriving from the north, and also that mackerel usually swim near the surface, and herring near the bottom, or at some distance below the surface. It is probable that at this time when the herrings visit the neighbourhood of the Norfolk and Suffolk coasts, the bottom water is colder than it has been during the preceding summer, in consequence of the inflow of bottom water from the north. This does not explain why the herrings are absent in January, February, and March. But the herrings come to spawn, and there is some evidence that they retire northwards into deep water to feed. All that I would suggest is, that we do not know that the bottom water, where the summer herring spawn, is at its warmest when the spawning takes place off Lowestoft, although, according to Dickson, the mixed Atlantic water which makes its way down the east coast of Scotland in summer is warmer than the water it displaces. The warmth of the inflowing water, however, is not very great, its temperature is not above 9° C. We have seen that, according to the observations of the *Pomerania*, the temperature at the bottom in the northern part of the North Sea in summer is frequently below 8° C., and we do not know what the winter temperature is. The hypothesis that the arrival of herrings is connected with a greater supply of oxygen, seems to be inconsistent with the fact that there is at all times of the year such an abundance of bottom fish (haddock, plaice, cod, etc.) in the places where the summer herring fishery is carried on.

We have seen that Pettersson traces a distinct connection between the herring fishery in the Skagerack and Cattegat, and the inflow of coast water. But there appear to be two periods of inflow, one from the south of warm water 15° C. to 16° C. in temperature in August and September, and one from the north of cold water 4° to 5° C. in January, February, and March. Herring fishery is associated with both of these, but principally, it would appear, with the northern water, which contained northern forms of plankton. It is well known that there are winter spawning herring in various localities, which must be considered to be races quite independent of the summer spawners. With regard to the relation of the fish to temperature, it is suggestive that on the south-west coast of England, in the neighbourhood of Plymouth, there are no herrings in summer or autumn, but only from about the end of November till the end of February, that is at the time when the water is coldest.

Dr. John Murray considers that there is evidence that the herrings of Loch Fyne and the Firth of Clyde reside there permanently, and do not merely make periodical visits, and believes that they feed chiefly in the deep depressions near the bottom. Whether these are the herrings which spawn on the Ballantrae Banks in early spring, we cannot definitely decide at present. But enough has been said to show that the introduction of Atlantic water with a greater supply of oxygen is not a sufficient explanation of the annual migration of summer herrings into the North Sea, and that probably some important and interesting discoveries have yet to be made concerning the relation between the food, breeding, and movements of herrings, and the temperature of the water in which they are found at different seasons.

(3) *Different sizes of fish of the same species at different parts of its habitat.* Mr. Holt's observations, together with my own, as published in previous numbers of this Journal, have shown the different sizes of plaice in (1) the northern and western part of the North Sea (2), on the south coast of Iceland (3), in the southern shallow part of the North Sea and in the English Channel. In the two latter cases the difference has been precisely exhibited in the lengths of the smallest mature and largest immature specimens. This is probably the best method of testing the matter, for the average size of mature specimens as a standard is liable to the objection that it depends on the extent to which older and larger fish are captured. Mr. Holt's observations in the Journal, and Petersen's * in the Annual Report of the Danish Biological Station, refer to small races of plaice in the Baltic. There are three points to be taken into consideration in relation to these

* Dr. C. G. Joh. Petersen, the Danish biologist, is not to be confounded with Prof. Pettersson, the Swedish hydrographer.

size-varieties or geographical races: (1) that their occurrence in the plaice is only one instance among a number, several other northern species, *e.g.*, the Greenland bullhead, *Cottus greenlandicus*, and the so-called Norway haddock, *Sebastes norvegicus*, being very much larger on more northern coasts than on British coasts or on the south coast of Norway; (2) the question whether definite structural peculiarities are present, as well as mere size, to distinguish the geographical forms from one another; (3) the question whether the differences are hereditary, each race breeding and transmitting its peculiarities independently, or whether the fish are the offspring of parents from other areas, and owe their peculiarities merely to the conditions under which they have lived and grown.

With regard to the first point, we cannot say that the existence of geographical races differing in size is peculiar to northern forms, although it is to these that my attention has been principally directed. It is probable enough that any wide-spread species may be found to show the same state of things. At a certain part of its habitat it appears that a species attains its greatest development, because there the conditions, whatever they may be, are most favourable to it, and at regions lying near the limits of its range it is less favourably circumstanced, and is found in smaller numbers and of smaller size. In Greenland it is stated that the short-spined bullhead attains to six feet in length, although it is the same species as the *Cottus scorpius* occurring on the east coast of Britain, where it never exceeds a length of fifteen inches. It is very difficult to decide what are the favourable and unfavourable conditions which cause the differences in size in such cases, and the investigation of these conditions would be both important and interesting. With regard to the plaice and other northern species, it might be supposed that a higher temperature was the chief unfavourable condition, and it may probably enough be one of them. We know that the water of the Channel is warmer than the bottom water of the northern part of the North Sea, and this higher temperature extends for great part of the year to the southern narrower area of the North Sea. But on the other hand, the Baltic, which contains plaice of small adult size, is colder, except perhaps in the height of summer, than the North Sea. Here it might be supposed that the lower salinity was an unfavourable condition, but this would not apply to the English Channel. It is possible that the amount of available food, the extent of suitable ground, and the competition of other species, have more influence on the size and general development of a particular species than purely physical conditions such as salinity and temperature.

With regard to the second point, it is found in many cases that minute structural peculiarities do co-exist in geographical races together with limits of size. Such races, therefore, must be regarded as incipient species; they only differ from species in the minuteness of the structural peculiarities and in the absence of definite limits between one race and another, a continuous transition from one to the other being observed in individuals and in intermediate areas. The study of such geographical varieties is therefore philosophically important, since in these cases we have actually the origin of species before our eyes.

Mr. Holt has previously written in this Journal concerning the ciliation of the scales in the males of the dwarf variety of plaice in the Baltic, and mentioned that these plaice have been stated to have a smaller number of dorsal and ventral fin-rays. Dr. Heincke had suggested that the Heligoland plaice were smaller than those of the western side of the North Sea, and probably formed a local variety. Dr. Georg Duncker, at Heincke's request, has investigated,* by the method applied by the latter to races of the herring, the distinguishing characters of local varieties of the plaice. He examined separately specimens from Greifswald, Kiel, the Cattegat, all localities in the Baltic, and from the neighbourhood of Heligoland. It appears from Duncker's results that ciliation restricted to the middle rays of the dorsal and oval fins is more common than a greater extension of the condition. It was more developed in specimens from Kiel and the neighbourhood than in those from the Cattegat, and in specimens from Heligoland was found on the body in two males out of 35, on the fins alone in 18 out of 35. But unfortunately no examination was made of specimens from other parts of the North Sea, and therefore it remains an open question whether the plaice of the Heligoland Bight have the special characters of a local race. Only a small number of specimens altogether were examined by Duncker. It will be remembered that my own examination of the size of mature specimens went to prove that the plaice of the Heligoland region were not smaller at maturity than those of the north-western part of the North Sea. The examination of specimens from the different regions of the North Sea, for the purpose of ascertaining whether constant structural differences can be found distinguishing the local forms, is yet to be carried out.

With regard to the third point, whether the peculiarities of local races are hereditary, or are acquired by the individual in consequence of the conditions under which it has lived and grown, to decide upon this, it would be necessary to know in each case how far interchange of

* Variation und Verwandtschaft von *Pleuronectes flesus L.* und *Pl. platessa L.*: *Wissenschaftliche Meeresuntersuchungen. Neue Folge, Erster Band, Heft 2, 1896.* (See this Journal, vol. iv. p. 293.)

individuals takes place between different areas, or whether the individuals of a region are the offspring of parents which lived in the same region. At present it is difficult to give answers to these questions. The English Channel is so extensive that we can confidently conclude that the plaice found there are the offspring of parents that also lived there. But we cannot be certain that the eggs of plaice which spawn between Lowestoft and the Dutch coast are not carried by the currents to some distant region, most probably to the Heligoland Bight, where they would develop into plaice of larger size at maturity. Similarly we cannot be certain that young plaice on the German coast near Heligoland are the offspring of parents which themselves grew up on that coast. To obtain evidence on these matters we must trace with more certainty the movements of the adult fish, and the course which the eggs are compelled to take by the currents. Something has been done in this way by the hydrographers, and by Dr. Fulton in his experiments with floating bottles, and the results indicate that the plaice of the Heligoland Bight are largely derived from spawn shed in the central part of the North Sea. In the Western Baltic the plaice have marked characteristics, distinguishing them even from those of the Cattegat, especially in the small size at which they are mature. Yet according to Petersen, young plaice, in the first summer after their development from the egg, are not found in the Baltic east of Zealand, Moen, and Falster at all, but enter it from the Cattegat when a year old. At the same time, Petersen finds indications that the mature fish in the Baltic emigrate through the Great Belt and spawn in the Cattegat, so that the dwarf plaice of the Baltic, with all their peculiarities, might be the offspring of parents which lived in the Baltic.

Note on a Specimen of Echinorhinus spinosus.

By

F. B. Stead, B.A.

A SPECIMEN of this somewhat uncommon shark was recently brought to the Laboratory by some fishermen. The following notes on it may be of interest. The fish was taken with a long line baited with mackerel, for conger. It was captured forty miles south of the Mewstone, at a depth of about forty-five fathoms. The specimen was a female, and measured 6 feet 6 inches from the end of the snout to the tip of the tail. The following are the principal other measurements: snout to anterior edge of first dorsal fin, 46 inches; snout to anterior edge of pectoral, 20 inches; the interval between the anterior edge of the pectoral and the pelvic fin was 26 inches. The first dorsal, which was small, was thus situated immediately above the pelvic. The second dorsal, which was smaller than the first, was situated as nearly as possible midway between the first dorsal and the commencement of the caudal fin. The measurements so far tally with Day's description of the species.

Attention may, however, be drawn to the measurements which follow in connection with the following statement in Day: "Ventral (fin) . . . commences mid-way between the front gill opening and the end of the caudal fin in elongated forms: or anterior end of the snout and middle of the caudal fin, as observed in the Plymouth and Aberdeen stouter specimens." (Day's *British Fishes*, vol. ii. p. 323.)

In my specimen the distance from the front gill opening to the anterior edge of the ventral was 30 inches: thence to the end of the caudal was 33 inches. On the other hand, the distance of the anterior edge of the ventral to the middle of the caudal was 26 inches, and to the end of the snout was 44½ inches.

It will be seen that my specimen corresponds to one of the "elongated forms," and not to the "stouter specimens," said to have been observed in Plymouth. Considering the relatively small number of specimens of this shark which have been captured and measured, the distinction between the elongated and stouter forms is perhaps hardly justified, and the measurements above recorded show that Plymouth specimens do not invariably belong to the latter class.

In other respects my notes as to the external features of the fish agree with Day's description.

The specimen was sent to the Museum of Zoology at the University of Cambridge, and I am indebted to Mr. S. F. Harmer for the following further facts in connection with it:

The ovaries were undeveloped: there were no large ovarian eggs, and the oviducts were quite small.

It should be noticed in this connection that the specimen was probably not full-grown. Day speaks of a female 9 feet long, containing 17 eggs, as having been taken off the Eddystone, and mentions a male 6 feet 2 inches long "having two large lobes of milt."

In various parts of the alimentary canal specimens were found of the parasite *Distomum insigne*. Several of these were attached to the roof of the pharynx; two were in the stomach, and appeared to be partially digested; one was in the small intestine, and several among the turns of the spiral valve. The alimentary canal contained nothing else except some glairy material and a few Isopods belonging to the species *Conilera cylindracea* (Montagu). One of these was in the stomach, and *alive*, though very sluggish; the others were in the large intestine, in the folds of the spiral valve, and appeared to be partially digested. There was nothing else recognisable in the alimentary canal.

In some of the specimens referred to by Day, it is stated that dog-fishes were found in their stomachs, and in one specimen there were no fish, but remains of Crustacea. Day further quotes a suggestion made by Mr. Cornish, that there are two permanent varieties of this shark—"one a ground-shark: the other a round or swimming." I have not been able to find the evidence on which this suggestion was based.

How do Starfishes open Oysters?*

By

Dr. Paulus Schiemenz.

MANY inhabitants of the sea know as well as men do that oysters are good to eat, and the destruction which they suffer on this account can scarcely be less than that brought about by human agency. Starfishes especially extirpate them in great numbers, and Möbius† maintains that they are the most pernicious enemies which the oyster possesses, although, on the other hand, people have not been wanting who held the destruction of oysters by starfishes to be a fable.‡

Collins|| calculates the damage done by these voracious robbers on the oyster beds of Connecticut alone for the years 1887, 1888, and 1889, at 463,600, 613,500, and 412,250 dollars, whilst that done in all other ways, by molluscs, mud, frost, etc., only represented a total of 39,200, 46,750, and 52,450 dollars.

In view of this enormous injury caused by starfishes to the oyster beds, it will be worth while to endeavour to obtain a clear idea of how a starfish really succeeds in eating an oyster. It is generally known that bivalve molluscs, and amongst them oysters, can close their shells so tightly against enemies that considerable force is necessary to open them, and the question arises, Is a starfish able to exert that force?

For the purposes of our discussion, we shall divide the starfishes which attack molluscs into two groups. Those of the first group have

* *Mittheilungen des Deutschen Seefischereivereins.* Bd. xii. No. 6, 1896. Translated from the German by E. J. ALLEN.

My thanks are due to Professor Dr. Henking, the general secretary of the German Sea Fisheries Association, both for permission to publish the translation of this article, and also for the loan of the blocks from which the figures are printed. E. J. A.

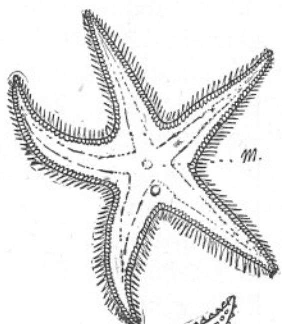
† MÖBIUS, K. "Ueber die Thiere der schleswig-holsteinischen Austerbänke, ihre physikalischen und biologischen Lebensverhältnisse." *Sitz.-Ber. Akad. Berlin.* 1893, pp. 67–92.

‡ FISCHER, P. "Faune conchyliogique marine du département de la Gironde." *Act. Soc. Linn. Bordeaux.* Tome 25, 1864, pp. 257–344.

|| COLLINS, J. W. "Notes on the oyster fishery of Connecticut." *Bull. U.S. Fish. Comm.*, vol ix. pp. 461–497, 1891.

conical shaped arms, increasing in width from the apex to the base, the united bases forming a more or less marked central body (*m*, Fig. 1*a*). *Astropecten aurantiacus*, which is common at Naples, may be taken as the representative of this group.* It lives in places where there is more or less deep sand, half buried in which it pursues its prey. The latter consists, for the most part, of bivalves and gasteropods which also bury in the sand, and the starfish forces them, by means of its flexible tube-feet, into its mouth, which is capable of a very remarkable degree of extension. The number and size of these molluscs which an *Astropecten*

FIG. 1*a*.



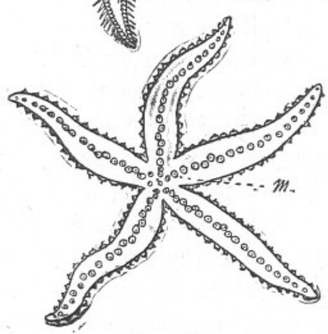


FIG. 1*b*.

is capable of swallowing passes belief, and the naturalist who keeps one of them in confinement is often astonished to find, sooner or later, quite a collection of shells in the dish, all of which had been concealed in the huge stomach of the starfish. Hamann† counted at one time ten *Pecten*, six *Tellina*, several *Conus*, and five *Dentalium*.

In the second group of starfishes (Fig. 1*b*) the arms are far from being so conical in shape, but are more or less cylindrical; indeed in the immediate neighbourhood of the body they are somewhat smaller than a little further off, and hence no true body exists. The members of this

* *Astropecten irregularis* may be taken as the representative of this group in British seas. E. J. A.

† HAMANN, O., *Beiträge zur Histologie der Echinodermen*. Heft 2. "Die Asteriden anatomisch und histologisch untersucht." Jena. G. Fischer, 8vo., 1885.

group, *Asterias glacialis,* for example, prefer rocky places, or at least hard ground, to a sandy bottom. *Asterias* devours all animals which it can overpower, having, like *Astropecten,* a preference for bivalves (especially oysters) and gasteropods which lie free on the surface. On account of the small size of the disc, the mouth of *Asterias* is capable of very little enlargement, and it would never be able to swallow oysters, which are its favourite food. Moreover, oysters remain firmly fixed to the bottom, and gasteropods also can often hold on so fast that it appears impossible that they should be passed into the stomach through the mouth. *Asterias* therefore takes up exactly the same position as Mahomed. As the mountain did not come to the prophet, the prophet went to the mountain, and as *Asterias* cannot bring his prey into his stomach, he sends his stomach into his prey, that is to say, he throws his stomach out like a proboscis, either wrapping it around or forcing it within the shell of his victim, and in this way digests it entirely outside his own body. The throwing out of the stomach of the starfish has been often seen and described: amongst others by Eudes-Deslonchamps,* McAndrew, and Barrett (according to Bronn), Forbes,† Rymer Jones,‡ Bronn,‖ Eyton,§ Schmidt,¶ Hamann,** and Möbius.††

The following example will show how cleverly *Asterias* can force his stomach through openings which appear little adapted to the purpose. One would think that a sea-urchin, with its thick array of movable spines, would be safe from the attacks of a starfish; but this is really not the case, as I was myself able to observe, through the kindness of Sgr. Lo Bianco, the conservator at the Naples Zoological Station. A moderately large sea-urchin was attacked by two starfishes, one on either side. One of these had only just commenced the onslaught. It had thrown its stomach through the narrow space between the spines until it reached the skin of the urchin, which, together with the muscles that attach and move the spines, it devoured, so that the spines by degrees fell off. The second starfish had in this way, as one might say, already digested for itself a road through the spines, and with its stomach had reached the mouth of the urchin. Through this, in spite of the urchin's strong teeth, it had inserted its proboscis, and so sucked out its victim like an oyster.

* EUDES-DESLONCHAMPS, "Notes sur l'Astérie commune." *Ann. Sci. Nat. Paris, Zool.* Tome 6, pp. 219–221, 1826.

† FORBES, EDW. *A History of British Starfishes and other animals of the class Echinodermata.* London 8vo., 1841.

‡ RYMER JONES, *Frorieps N. Notiz.* Bd. 12. Nr. 288, 1839.

‖ BRONN, H. G., *Klassen und Ordnungen des Thierreiches.* Bd. 2. Actinozoa, 1860.

§ EYTON, T. C., "A history of the oyster and the oyster fisheries." *The Edinburgh Review,* vol. cxxvii. pp. 43–76, 1868.

¶ In Brehm's *Thierleben. Grosse Ausgabe. Aufl.* 2. *Abth.* 4. Bd. 2. Leipzig, 1878.

** *Loc. cit.* †† *Loc. cit.*

Astropecten and *Asterias* possess tube-feet of very different structure. Those of *Astropecten* are conical and quite pointed at the end, and seem extremely well adapted to boring in sand. Suckers at their ends are entirely wanting. Such enlargements would only be a hindrance when boring in sand. On the other hand, *Astropecten* has no need of suckers, for it does not climb steep walls; the animals which it preys upon all move so slowly that they could not escape by flight, and therefore do not require to be held fast; and thirdly, this starfish does not need to open its victims. With its feet it brings them into the capacious stomach, from which they cannot again escape. It has now only to quietly wait its time, until the animals, killed by suffocation, open their shells and allow the digestive juices to reach them.

In the case of *Asterias* the circumstances are quite different. The animal is a zealous climber, and by preference clings to perpendicular walls. If, like *Astropecten*, it possessed pointed tube-feet without suckers, it could not do this, but would fall down as *Astropecten* does when it attempts to climb in confinement. The animals which *Asterias* eats are some of them capable of relatively rapid locomotion, and therefore require to be held fast. Many of them, too, have the power of tightly closing their shells, and if the *Asterias* wishes to get at their soft bodies, the shell must first be opened. For clinging, as well as for opening shells, pointed feet would be quite useless. Feet, however, provided with powerful suckers, such as *Asterias* possesses, are well adapted to these uses.

There is, too, a difference between the ways in which the feet of *Astropecten* and *Asterias* move. Whilst *Asterias*, when the suckers have been loosened, curves the feet outwards, and so draws itself back, *Astropecten* curves them inwards. It is obvious that the latter mode of progression is much better adapted to a life buried in sand, such as *Astropecten* leads.

Different views have been expressed as to the manner in which *Asterias* and similar forms succeed in opening the shells of molluscs. At the present time it seems to be generally considered that this is accomplished by the secretion of a stupefying fluid, or poison. As we shall see, however, further on, this view is a complete mistake.

In what follows we shall consider (1) the possible methods by which the opening of the shell could be accomplished; (2) which of these is to be considered the most probable; and, finally (3), we shall endeavour to prove that this method is, in fact, adopted. There appear to be altogether six possible ways:—

1. *The starfish might take the molluscs by surprise.*—Bivalves, including the oyster, are generally very watchful. A small change of light, a shadow, a slight movement of the water, or any trifling disturbance,

immediately causes the closing of the shell. Such sensitiveness seems to preclude completely the idea of their being surprised by the starfish, for before the latter could reach, say, an oyster with its mouth or its everted stomach, it has already freely touched it with the feet on its long arms, and thereby given it sufficient warning. But even if the oyster allowed itself to be taken by surprise, as soon as ever it felt the stomach of the starfish on its soft parts, it would immediately close the shell, and the starfish would generally only be able to escape by tearing off its stomach. If anyone is not prepared to accept this without further proof in the case of the oyster, he has only to consider, say, a *Venus*, with its strong shell-margins, which, when closed, do not let the very finest crevice be seen, and which would at once crush such a soft body as the stomach of a starfish. According to Forbes, it is the belief of some oyster-fishermen that *Asterias* insinuates an arm into the oyster's gape in order to devour it. The oyster then closes, and the starfish is caught. To free itself again, and not die miserably of hunger, it elects to sacrifice an arm, and this is the reason why so many mutilated starfishes are found. This is a very pretty fable, but it is no more than a fable, for a starfish of moderate size does not insert an arm into a living oyster, for the simple reason that the gape of an oyster, when open, is much too small.

2. *The starfish might beset the oyster so long that it would be compelled, by hunger and want of air, to open.*—This supposition is made by the brothers De Montagué* and by Smiley.† To say nothing of the possibility that, in this case also, the stomach might easily be bitten off by a renewed closing of the shell, the duration of the attack would be a very long one, for it is well known that bivalves, and especially the oyster, can remain closed for a great length of time without air and nourishment. I fancy that during this long siege the starfish would get such a strong appetite itself that it would prefer to look around for more manageable prey. Moreover, the supposition stands in direct contradiction to an observation of my own, according to which from fifteen to twenty minutes is generally sufficient for the opening of a *Venus*.

3. *The starfish might hypnotise the molluscs.*—It is known that certain animals, if their bodies are placed in a quite unaccustomed attitude, are subject to a kind of hypnotism. According to Apgar,‡ if a *Unio*, for example, is seized quickly, and the shell firmly pressed, so that the

* De Montagué, frères, "Etudes pratique sur les ennemis et les maladies de l'huître dans le bassin d'Arcachon." *Act. Soc. Linn. Bordeaux*, vol. xxxii. (4 ser. Tome 2). 1879.

† Smiley, Chas. W., "Notes Upon Fish and the Fisheries." *Bull. U.S. Fish. Comm.*, vol. v. 1885. (From a statement by Capt. S. J. Martin.)

‡ Apgar, Austin C., "The Musk-rat and the Unio." *Journal Trenton Nat. Hist. Soc.*, vol. i. pp. 58, 59; also in *Zoologist* (3), vol. ii. pp. 425–426.

protruding foot is squeezed, after half to three-quarters of a minute it becomes paralysed, and can make no more use of the adductor muscles. Apgar believes that the musk-rat (*Fiber zibethicus*) takes advantage of this fact in order to get at the soft parts of the mussel. In the case of the oyster, however, anything of this kind does not apply, for it cannot be brought into an unaccustomed attitude, nor has it any foot to protrude and be squeezed. This could, however, happen with other bivalves which are not fixed and which possess a protruding foot; for, whilst being eaten, these are constantly placed by the starfish in a position quite the reverse of the normal one; namely, with the hinge below, and the gape above. I have tried experiments on the point with *Venus verrucosa*, but have failed to notice any hypnotic or paralytic effect. I have made a *Venus* stand for many hours on the hinge, and have afterwards found exactly the same resistance to forcible opening as at other times. Since, however, the starfish can effect the opening in from fifteen to twenty minutes, the possibility of hypnotic effect is precluded.

4. *The starfish might make an opening in the shell with the help of a boring apparatus or an acid.*—No boring apparatus is possessed by *Asterias*, and the holes which one often finds in oyster shells are due to gasteropods, and not to starfish, although they have sometimes, in error, been ascribed to the latter; *e.g.*, by Ball and Forbes. I have neither been able to find holes in the shell of a *Venus* which has been devoured, nor an acid reaction in the everted stomach. It is, however, a difficult thing in sea water, which is slightly alkaline, to demonstrate an acid with litmus paper; but when we recollect that the opening is effected in so short a time, the acid would necessarily require to be very strong, and should be capable of demonstration even under such unfavourable conditions. One does often find regular holes on the shell-margin of oysters which have been eaten, but, as we shall see presently, these are produced, not by boring, but by breaking.

We come now to the possibility—

5. *That the starfish pours a poison over, or, rather, within the shell of its victim, whereby the muscular force of the latter is enfeebled, and the shell opened.*—In itself this is not unlikely, and I was at first of opinion that this was, in fact, the method by which the opening was effected, for it is known that many animals maim their victims by poison, derived generally from the salivary glands, before devouring them. However, even this power would not be of much use to the starfish. As already mentioned, a *Venus*, for instance, squeezes its shell so tightly together that one could almost speak of its being hermetically closed. A poison poured over the shell could not penetrate, but would flow off without effect. In this case also it would be first necessary to

bore in the shell an opening through which the poison could be injected. However, as we have seen above (*cf.* 4), no such boring of the shell does, in fact, take place. The action of poison was assumed by Eudes-Deslonchamps, Forbes, Rymer Jones, Bronn, Eyton, O. Schmidt (in Brehm), and Smiley (following Captain Martin). Hamann attempts a detailed description of the process; but, for myself, I fail to see upon what logical grounds, from the presence of a slimy fluid and the opening of the bivalve, a proof for the secretion of poison can be derived. It is not even shown whether the slime comes from the starfish or from the bivalve, and it is a fact, which anybody can easily observe, that bivalves and gasteropods commence a copious secretion of slime if their soft parts are handled. I have, however, made experiments which demonstrate quite certainly that *Asterias* does not secrete a poison, or, rather, that a maiming of its victim by this means does not take place. A *Venus verrucosa* was offered to an *Asterias* which had fasted for about a week, and was greedily taken. Whilst the starfish was busy opening, or, rather, eating this *Venus*, a second one was offered it. This also was immediately taken and, for the time, held fast, its hunger, after the long abstinence, not being satisfied in a moment. When the first mollusc was finished, and its empty shell thrown away, the second was carried by the tube-feet to the mouth, and brought into the usual position. In a short time this one also was opened, and opened extremely wide, but the stomach of the starfish was not thrown out, the animal being satisfied with what he had in hand. The *Venus* was now taken away from the starfish, whereupon it immediately closed, and was laid in a dish with sand. It was not long before it disappeared in the sand in the usual manner, and it afterwards continued quite normal. Specimens of *Venus* were, in a similar way, taken from other starfishes at different stages of the process of opening, and before digestion could commence. The result was always similar to that in the first case described, and the animals showed no trace of maiming or other disturbance. Experiments were also undertaken with gasteropods, and these were even more instructive, because the creatures are much livelier, and therefore promised to show more readily any disturbance of their organism. It was, at the same time, possible easily to observe directly all the details of what took place. I chose for these experiments my old friend *Natica* (sp. *millepunctata* or *ebrea*). Whilst experimenting I made a not uninteresting observation, which completes in a satisfactory way some work which I had formerly published. In a paper on the absorption of water by molluscs,* I had tried to establish the physiological significance of the

* SCHIEMENZ, P., "Ueber die Wasseraufnahme bei Lamellibranchiaten und Gastropoden (einschliesslich der Pteropoden)." 2 Theil. *Mitth. Zool. Stat. Neapel.* Bd. 7, pp. 423-472. 1887.

separate parts of the foot of *Natica*, and in a later paper* I added a further contribution to the subject. I was not quite clear at that time as to the significance of the "shell lobe" (Fig. 2, Sch. Lap.); that is to say, the portion of the foot which, in *Natica josephina* almost entirely, in *N. millepunctata* and *ebrea* only partially, under ordinary circumstances, covers the shell. I have now, however, been able to observe with certainty the use to which this portion of the foot is put. If a few *Natica* be placed in a dish in which there are some *Asterias*, rendered hungry by fasting, the molluscs immediately begin to creep about, and the starfishes endeavour to overpower them. The tube-feet of the *Asterias* are unable to fix themselves to the body of the *Natica* on account of its slimy surface, and there is only left them the uncovered remnant of the shell. (Fig. 2, Sch.) But here also the attachment is prevented, for the moment the *Natica* comes into contact with a starfish it pulls the "shell lobe" of the foot with a jerk over the previously uncovered part of the shell, and thus there is no place left to which the

FIG. 2.

suckers of the *Asterias* can fix. I have observed this proceeding a great many times, and it always takes place so promptly that there can be no doubt as to its connection with the means of defence against starfishes. The drawing of the shell lobe over the shell is brought about by the contraction of the transverse, or, rather, annular muscles of the lobe margin, which act like a sphincter.

In nature, of course, *Natica* hardly comes in contact with *Asterias*, but it does come in contact with *Astropecten*, and it is clear that the tube-feet of that animal, though they are quite pointed at their ends and have no suckers, will slip from the slimy surface of the *Natica* just in the same way as the tube-feet of *Asterias*.

If a *Natica* in the contracted state be given to an *Asterias*, the latter fixes its tube-feet upon all parts of the shell of the mollusc, carries it to its mouth, and tries to digest it. If the *Natica*, however, has lived for some time in the dish and become used to the conditions of confinement, it does not through terror remain closed, but, as a rule, comes out of its shell immediately, and endeavours to free itself from the starfish. A

* SCHIEMENZ, P., "Wie bohrt Natica die Muscheln an?" *Mitth. Zool. Stat. Neapel.* Bd. 10, pp. 153–169. 1891.

hard fight now commences. As soon as the mollusc begins to protrude its foot, the starfish also throws out its stomach and endeavours to commence the work of digestion. By feeling here and there with the margin of the anterior angle of the foot, which serves as a sense-organ, the gasteropod now tries to find a place somewhere between the tube-feet where there may happen to be a larger space, offering a chance of escape. As is natural, the starfish on its part makes convulsive efforts to hold its victim fast, and block every possible way of escape through the forest of tube-feet. If the *Natica* succeeds in protruding the fore part of its foot sufficiently far for the corners, upon which the apertures for taking in water are situated, to expand themselves, then the battle has been won. When it has made the fore part of the foot swell up a little, it swells the hind part, and from this the shell lobe; whereupon, by drawing the latter closely and tightly over the shell, it sweeps off all the suckers of the starfish. As soon as this has happened the mollusc is free and creeps away unhindered, in spite of the fact that the starfish, during the whole time, has partially covered it with its everted stomach. Thus no maiming by poison has taken place. As a further confirmation, though this was hardly necessary, I took away from the starfish a couple of *Natica* which had not been able to free themselves, and had been already somewhat digested during the fight, and bore wounds. These also recovered; so that there can be no talk of poisoning. Naturally the fight often ends in the destruction of the *Natica*, especially when the starfish has fixed a great number of feet on the operculum and just behind it; for it is then impossible for the mollusc to protrude its foot far enough to be able to swell it up. If the gasteropod perceives the uselessness of the attempt to escape, it withdraws into its shell, closing the latter with the operculum; and then the starfish must first of all open it again. For this purpose there remains one more possibility, namely:

6. *That he opens the shell by force.*—This supposition will be doubtless at first opposed by every reader, who knows from his own experience the strength with which bivalves and gasteropods can keep their shells closed. If, however, we consider the position into which the starfish brings his victim when he wants to open it, the supposition becomes more likely.

With oysters and fixed bivalves and gasteropods, *Asterias* cannot do very much: he must take them as they lie, and cannot alter their position. The circumstances are quite different, however, when he is dealing with a free-living mollusc. If we bring a *Venus* to the end of an arm of a hungry starfish, the first thing it does is to taste it with the long tube-feet, serving as sense-organs, which are situated there. In a few moments the many hundred tube-feet, with which it has been quietly holding on, come to life, and the whole animal pushes itself towards the side at which the mollusc is offered. The arms next to the ones touched are immediately brought near it; and with these three, or perhaps only with two of them, the *Venus* is held fast, the arms being gradually pushed over its shell and one sucker after another made fast to it. But the starfish does not stop moving as soon as the arms have reached the far side of the bivalve, and as fast as they are pushed beyond it the tube-feet fix themselves to the ground. Only when the *Venus* has in this way reached the middle-third of the arm does the starfish cease the forward movement and remain stationary. Meanwhile the bivalve is carried further forward by the tube-feet until it reaches the mouth of the starfish, and is there turned round into such a position that the hinge is below, and the margin of the gape lies exactly opposite the mouth of its enemy. (Fig. 3.) Hamann has already made mention

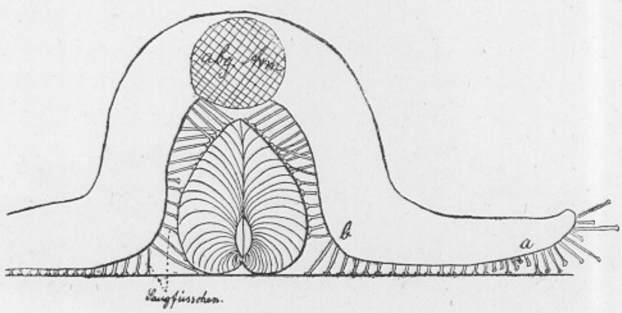


FIG. 3.

of this position. Whilst this is going on, the starfish raises its body and the portions of its arms next it into a peculiar mound, as represented in Figs. 3 and 4. The only writer I can find who makes mention of this curious attitude is Möbius.* When the starfish is resting on the bottom of the dish, what happens inside this mound, one is not, of course, able to see. In order to find out, the animal must be induced to ascend one of the vertical glass sides of the dish, which is not at all a difficult thing to do. By holding a mollusc in front of it, a hungry starfish may be enticed over considerable distances and led round the dish. If one does this too much, however, it ceases to respond; or, when the mussel is again offered after an interval, begins to crawl away.

It might at first sight appear as if this rising into a mound served only to hinder the victim from escaping. Apparently this is one of the reasons for it; for in assuming the position the arms are pressed together so tightly that not even a crevice is left through which escape could be effected. But a consideration of Fig. 3, which to some extent represents

* MÖBIUS, K., *Die Auster und die Austerwirthschaft*, p. 120. Berlin, 1877.

a section of Fig. 4, makes it at once evident that if the starfish intends to open the bivalve by force, he can only do so after he has brought himself and his prey into the positions there represented. I will not here go further into physical considerations, but only remark that the mound itself is extraordinarily rigid, and offers very great resistance to any attempt to press it down. The starfish can now divide its tube-feet in such a way that half of them are fixed to one valve of the shell, the other half to the other; and a pull in opposite directions can be exerted upon the two valves. If the mound formation is adopted in order to open the mussel in the manner indicated, a starfish which is prevented from adopting such a position will not be able to succeed in opening a free bivalve or gasteropod. I therefore made the following experiment: I took a small vertical dish with glass sides, and, by means of a glass

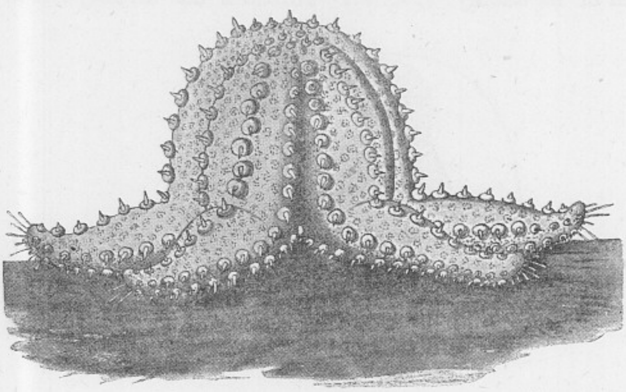


FIG. 4.

plate, separated off a compartment in which there was just depth enough for a starfish to creep, but in which he could not form a mound. When I had put a starfish, which had been prepared by previous fasting, into this small compartment, I offered him a closed *Natica*, which he immediately took. Now whereas, under ordinary conditions, provided a long fight did not take place, a starfish would open a *Natica* in a relatively short space of time,* this starfish wandered round the dish for nearly a whole day, from morning till evening, with his victim—which all the time remained closed—without managing to digest it.

It was only towards evening, after many vain attempts, that by all sorts of contortions of his arms he succeeded in forming a mound in a quite unnatural way, namely, between the glass sides and in a position

* There is no need to explain further that gasteropods are opened in exactly the same way as bivalves; some of the tube-feet of the starfish being fixed to the shell itself, whilst others are fixed to the operculum. The gasteropods are brought into an exactly similar position.

parallel to them. Then he set about opening and digesting the *Natica*. This result clearly confirms the correctness of the above supposition.

In the case of oysters the circumstances are different, in so far that, under natural conditions, these animals are fixed to the ground, and are also considerably larger than the other bivalves. If a starfish, wishing to open an oyster, can find suitable points for fixing his arms on the objects which lie around, it will give him no great trouble to pull his victim apart. Should he not, however, find these, he must form a mound exactly similar to that in Fig. 3. Physical considerations, however, show that under these circumstances, since he must support the portion of the arms marked *a—b* in Fig. 3 on the oyster itself, there will only be a prospect of success when this point of support of the arms lies quite far towards the hinge, or even beyond it, so that the

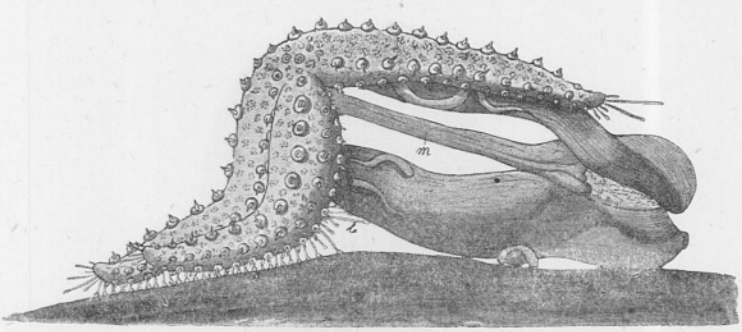


Fig. 5.

arms can mutually assist each other. There must therefore always be a definite size-relation between the oyster and the starfish; and from this it follows further that large oysters are relatively safe from the attacks of starfishes, whilst small and medium sized ones are specially liable to destruction. Perhaps some day an oyster fisherman will collect evidence on this point. In relation to the matter I must, however, remark that an oyster can only be regarded as successfully attacked when it has been actually opened; and a simple attempt on the part of the starfish of itself proves nothing. In the figures which Collins gives on Plate 165 (Figs. 1 and 2), the size-relation under discussion is clearly seen; and I believe I am not mistaken when I imagine that I can see in the positions of the starfishes in these figures the mound formation which I have described.

In Fig. 5, which I give here from an observation of my own, the starfish has already completed the work of opening; and has, indeed, already digested the greater part of its victim. There is nothing more to be seen of a mound formation, since it is no longer necessary, on account of the destruction of the adductor muscle. I give the figure, nevertheless, because in this case the starfish has made use of the bottom of the dish as the point of support, or attachment, for a portion of the arms. The position of these arms is exactly the same as in Fig. 3: the feet on the parts near their centres (above *b*) being fixed to the oyster's shell, those on the distal parts (*a*) to the bottom of the dish. In the figure is seen also very clearly the manner in which the stomach (*m*) is thrown out, and what a significant position it occupies. That I have not succeeded in this case, as I was able to do with *Venus*, in directly observing the whole process of opening, was due to the fact that the oysters were opened by the starfishes at night. Whether this was accidental or not I cannot say. *Venus* and *Natica* were taken and opened at whatever time of the day they were offered.

Fig. 6.

An examination of shells which have been eaten out, also shows that the starfish pulls powerfully upon the shell of an oyster which he is about to devour. The margin of oyster shells, at least at Naples, is always more or less laminated. Now, in oysters which have been eaten out, the laminated margin of the upper shell is always broken away for a greater or less distance, until the deeper and stronger layers are reached. Fig. 6 shows such a shell; on which, however, the injured place was specially conspicuous. I need hardly mention that I carefully examined the margins of the oysters before giving them to the starfishes. As no other animals were in the dish excepting oysters and starfishes, the effect upon the shells of the oysters which were eaten could only be due to the starfishes. Moreover, I have seen such broken portions of shell directly attached to the suckers on the feet of a starfish which was resting upon an oyster. Such broken places I have only found on the flat shell, which is clearly due to the curved shell being less laminated, and, therefore, less easily injured.

The points, recognisable by the injury just described, at which *Asterias* opens the oysters, show a certain degree of definiteness in position. They do not, however, as I at first suspected, exhibit a perfectly regular relation to a line drawn through the hinge and the muscle scar. In general, indeed, they lie on this line, and this can be readily understood, since the two shells of the oyster represent, to some extent, two levers, with a fulcrum at the hinge. The further the point of seizure lies from the hinge, that is to say, the longer the arm of the lever, the more effective will be the force applied. Precisely on the longest shells, nevertheless (Fig. 7, Nos. 3, 6, and 10), we find the point of seizure lies, not on the line mentioned, but displaced quite

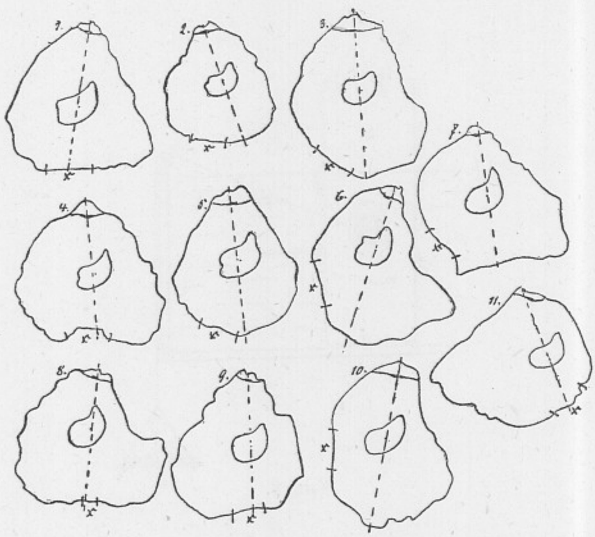


FIG. 7.

to one side. I can only explain this variation on the supposition that these oysters were of too great length in the direction of the line through the hinge and muscle for the arms of the starfish, and the latter had to find positions in which their arms could reach further over the shell. The point of seizure in these shells always lies on the side which exhibits the less vigorous growth. This seems to be a general rule in all cases in which the oysters show unequal growth (compare also Nos. 7 and 11 in Fig. 7), and possibly depends on the fact that on the side where there is less growth the shells are naturally less laminated, and the starfish, therefore, has more chance of coming to firm portions of the shell, upon which it can effectually fix its tube-feet. In oysters from other localities, whose shells are firm at the margin, and less laminated than those at Naples, such places as those just described, made by breaking away portions of the shell, will naturally not be found. On them, therefore, it will not be possible to ascertain the spot where the starfish has taken hold.

Thus, I have come to the conclusion that the starfish opens the shell of his victim by force, and I must now bring forward proof that the animal does actually possess sufficient strength for the purpose. To do this, the strength of a moderate-sized starfish must first of all be measured. As may be seen from Figs. 3, 4, and 5, the starfish does not use all its tube-feet in opening a bivalve, but, at most, only those on the central halves of the arms. In measuring the strength exerted,

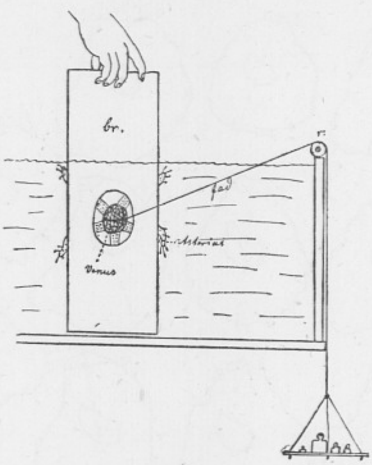


FIG. 8.

the other tube-feet, therefore, must be left out. I succeeded in doing this in the following way:—

A hole was cut in a board of a size corresponding approximately to that of the portion of the starfish which comes into play in opening molluscs. One side of the board was covered with a glass plate (in which was a corresponding hole), giving the starfish the opportunity of attaching itself firmly with the remainder of its tube-feet. An *Asterias* was now enticed with a bivalve on to the board, and the mollusc offered to him through the hole in the board. The bivalve itself was bound round with a string, which was passed, by means of a pulley, over the edge of the dish, and carried at its end a board upon which weights could be placed. After the starfish had taken the mollusc, weights were put on until it let it go. This happened with a weight of 1350 grams. This figure does not, however, represent exactly the strength of the starfish, but is considerably less. Indeed, I have observed that if one endeavours to pull away again a mollusc which has been offered it, a starfish will resist for some time, but if the pull lasts too long, or is too strong, it quite suddenly draws in all its tube-feet, lets the mollusc go, and cannot be persuaded to take it a second time. However, if we accept 1350 grams provisionally as representing the strength of the starfish, we shall, in what follows, be able to show that so much power is far from being necessary for the forcible opening of a moderate-sized *Venus.*

This sounds unlikely, especially since one knows that, according to Lawrence-Hamilton,* a *Venus* can, with its adductor muscles, withstand a strain equal to 2071 times its own weight (without the shell). I have myself seen that, with a momentary weight of 4000 grams, a

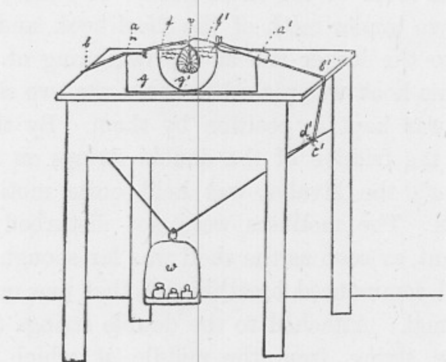


FIG. 9.

Venus does not think of opening. But the circumstances are completely changed when, instead of a momentary strain, a continuous one is applied. Everyone knows from his own experience that to lift a weight, and to support it for a long time, are two quite different things.

In order to investigate the resistance offered by *Venus* to a strain, I had a jar of sea water sent from Naples, followed, some days afterwards, by a number of *Venus verrucosa* (as samples without value) wrapped in moist linen. The latter arrived in Hanover in three days, and were in full vigour, protruding their siphons normally as soon as they were placed in their native element.

In order to measure their strength, I constructed, with the modest appliances at my disposal, the apparatus figured above. (Fig. 9.) The

* LAWRENCE-HAMILTON, J., "The Limpet's Strength." *Nature*, vol. xlv. p. 487. 1892.

apparatus had to be so devised that the bivalve, whilst remaining in water, could be placed in such a position that a measurement of the extent of opening of the shell could easily be made. A glass dish containing sea water (*g*) was placed on a small table. In this one stood a smaller but higher dish, also containing sea water, which could be renewed from time to time from the larger one. A *Venus* was now surprised, the handle of a scalpel being placed between the two shells before it had time to close them. The bivalve of course, as soon as the scalpel was put in, closed immediately, and held it fast, and so could easily be taken out. Two flesh-hooks were then taken: a short one made entirely of metal, with two teeth at each end (*f*), and a second one with a scalpel handle (*f′*). The two teeth at one end of the short hook were placed in the shell-opening. The teeth of the second hook were also placed in the opening in such a way that they came between the teeth of the short hook. A double string was then slung from the two hinder teeth of the short hook, and a similar string was made fast to the larger one at the beginning of the flat handle. The handle of this hook was placed between the two strings on its own side, so that it was kept in position by them. By this arrangement, with the aid of the friction of the double strings on the edges of the dish (at *a* and *a′*), the bivalve was held quite motionless, with the opening upwards. The molluscs were not disturbed by this experimental strain; but, as soon as the shell was far enough open, protruded their siphons and commenced breathing, so that one may say that they were simply normal. Attached to the double strings (at *d* and *d′*) was a single common string, from the middle of which a scale-pan (*w*) hung. The weights on this scale-pan were, of course, not all effective, on account of the considerable friction at the points *a*, *b*, *c*, and *a′*, *b′*, *c′*. In order to determine the true effective weight, I afterwards replaced the bivalve by a spring balance, which was pulled out by the weights. Such spring balances never weigh quite correctly; but in this case one or two grams does not matter, and I give, therefore, in the following tables, only round numbers (friction being allowed for):—

1. *Venus* 4 cm. long, 3·4 cm. broad.

7.55	a.m.,	loaded with 900 grams.
8.10	„	commenced to open.
8.15	„	open 2 mm.
8.30	„	open 3·5 mm.
1.0	p.m.,	open 3·5 mm.
6.10	„	open 4 mm.: then set free.

2. *Venus* 3·9 cm. long, 3·2 cm. broad.

6.15 p.m., loaded with 900 grams.
6.20 „ open nearly 2 mm.
6.30 „ open 4 mm.
7.5 „ open 6 mm.
8.7 „ open 5·5 mm. (because a lamp was brought near).
9.0 „ open 6 mm.
9.30 „ open 6 mm.
6.15 a.m. the next morning, open 6 mm.: then set free.

3. *Venus* 4 cm. long, 3·3 cm. broad.

7.0 a.m., loaded with 900 grams.
7.5 „ open 2 mm.
7.10 „ open 3·5 mm.
7.15 „ open 4 mm.
7.30 „ open 5 mm.

Load increased to 1250 grams.

7.38 a.m., load increased to 1700 grams.
7.46 „ load increased to 2000 grams.
8.10 „ open 7 mm.
8.15 „ adductor muscles ruptured.

4. *Venus* 3·6 cm. long, 3 cm. broad.

8.19 a.m., loaded with 900 grams.
8.40 „ open 3 mm.: then set free.

5. *Venus* 3·4 cm. long, 2·8 cm. broad.

8.40 a.m., loaded with 900 grams.
8.56 „ open 1·5 mm.
9.2 „ open 2 mm.
12.27 p.m., open 2·5 mm.

Load increased to 1000 grams.

2.0 p.m., open 2·5 mm.
6.45 „ open 2·5 mm.

Load increased to 1400 grams.

7.15 p.m., open 3 mm.
7.45 „ open over 3 mm.
9.50 „ open 4 mm.: then set free.

6. *Venus* 3·7 cm. long, 3 cm. broad.

9.50 p.m., loaded with 1000 grams.
10.15 „ open 2 mm.
10.30 „ open 4 mm.
11.30 „ open 4 mm.
7.0 a.m. next morning, found with adductor muscles ruptured.

7. *Venus* 3·3 cm. long, 2·8 cm. broad.

8.0 a.m., loaded with 900 grams.
8.24 „ open 1·5 mm.
9.45 „ open 2·5 mm.
10.20 „ open 3·5 mm.: then set free.

Several of the molluscs closed somewhat when approached or disturbed; but as long as the strain was continued they could never shut up completely, even when their soft parts were mechanically irritated. With the exception of the two which were torn apart, they all closed again completely and tightly immediately they were freed from the strain, and when left to themselves behaved quite normally.

It will be seen from the tables that different individuals resist the strain to a very different extent. Generally a weight of 900 grams* is quite sufficient to open a *Venus* in from five to twenty-five minutes, or, on an average, fifteen minutes. Further, it follows from experiments 3 and 6 that a strain of 2000, or even 1000 grams. exerted on both shells at once, is sufficient, if continued for some time, to rupture the adductors; whilst, according to the results both of Lawrence-Hamilton's experiments and of my own, not even a weight of 4000 grams is enough to bring about a sudden rupture. The difference in effect between a momentary and a continuous strain is thus most clearly shown.

We saw above that a starfish of moderate size can develop a force of at least 1350 grams with the tube-feet which come into play; so that it possesses more than sufficient strength to forcibly open a *Venus*, since for this purpose at most 900 grams is necessary. The conclusions we have come to are therefore completely confirmed by experiment.

What applies to a *Venus* applies also to an oyster; which, according to Lawrence-Hamilton, can only resist 1919·5 times its own weight (without the shell), and hence is somewhat weaker than *Venus*.

It hardly requires to be stated that every starfish cannot open every oyster or bivalve, and that the size and strength of the two must be in suitable proportion.

* I have not ascertained how small a load is necessary to cause a slight opening of the shell. It only concerned me to learn whether a weight of 1350 grams is large enough.

In order to afford an idea of the rapidity with which a starfish completely devours an oyster or bivalve, I may mention that a starfish of moderate size had completely digested a *Venus* 3·7 cm. long in $8\frac{1}{2}$ hours, and an oyster $2\frac{1}{2}$ cm. in diameter, which was given it open, in 4 hours.

In conclusion, I would point out that the oyster or mussel culturist should take the greatest pains to destroy starfishes wherever and whenever he can get hold of them. It is not sufficient, however, to tear them up, since they possess an extraordinary power of regeneration, and are able to replace lost parts in a relatively short time. The central body especially plays an important part in this process, and it is probably for this reason that (according to Forbes) regulations exist in certain parts of England which oblige the fishermen to tear or crush the central body of starfishes which they capture, before throwing them overboard. In many districts it would no doubt be worth while to bring the starfishes ashore, and use them as manure. The practical Americans have constructed a special dredge—the "star dredge"—an iron instrument carrying a number of tangles, with which they systematically capture starfishes on the oyster beds.

Algological Notes.

By

George Brebner.

THE following is a list of the most important finds since the report in the last number of this Journal.

NEW TO BRITAIN.

MYXOPHYCEÆ.

Oscillatoria rosea, Crn. (Queen's Ground).
**Symploca atlantica*, Gom. f. *purpurea*, Batt. in lit. (Yealm).
**Hyella cæspitosa*, Born. et Flah. var. *nitida*, Batt.

PHÆOPHYCEÆ.

Ralfsia disciformis, Crn. (Yealm).

FLORIDEÆ.

**Acrochætium endophyticum*, Batt. in lit. (Off west-end of Breakwater).
**Cruoria rosea*, Crn. f. purpurea, Batt. (Yealm).
Cruoriopsis cruciata, Duf. (Queen's Ground).
,, *Hauckii*, Batt. (Off west-end of Breakwater).
Peyssonelia rupestris, Crn. (Queen's Ground).

NEW TO PLYMOUTH DISTRICT.

CHLOROPHYCEÆ.

Cladophora hirta, Kütz. (Drake's Island).

PHÆOPHYCEÆ.

Lithoderma fatiscens, Aresch. (plurilocular sporangia, not previously found in Britain.) (Bovisand Bay).
,, *simulans*, (Kuck.) Batt.

FLORIDEÆ.

Acrochætium microscopicum, Näg. (Andern Point).
Peyssonelia Harveyana, Crn. (Queen's Ground).
Rhododermis elegans, Crn. (Queen's Ground, etc.).
Lithothamnion Strömfeltii, Foslie. (Queen's Ground).
Peyssonelia Rosenvingii, Schm. (Wembury Bay).

Those marked thus * are species, or forms, new to science.

The new species of *Acrochætium* is interesting on account of the main part of the thallus being endophytic, the sporangia being raised above the surface of its host *Dasya coccinea*, on short one—to a few-celled stalks. This plant therefore occupies a place in the genus *Acrochætium* similar to that of *Rhodochorton membranaceum* in its genus. The latter plant, however, is not endophytic, but grows within the polypary of various hydrozoa. *A. endophyticum* was described in its barren condition at the Linnean Society's meeting of 19th December, 1895. The sporangia were not found till January, 1896.

Cruoria rosea, Crn. f. *purpurea*, Batt. in lit., is probably only a more advanced stage in the life-history of *Cruoria rosea*, Crn., than had hitherto been recognised. It is so like the figure of Crouan's *Cruoria purpurea* that it would have been identified as such by Mr. Batters and myself but for the fact that our solitary specimen showed several intermediate stages.

Cruoriopsis Hauckii, Batt. in lit., is an interesting member of the Squamariaceæ, dredged off the west end of the Breakwater. The tetraspores showed almost every transition from zonate to cruciate. It most nearly resembles *Cruoriella armorica* of Hauck (non Crouan). As one of the two species bearing the name of *Cruoriella armorica* will have to be re-named, Mr. Batters proposes to call our plant as above.

The other finds do not call for special mention here.

Certain cultivation experiments were carried on which gave interesting results, chiefly with regard to the germination of spores. The most important of these was obtained in the case of *Ahnfeltia plicata*, Fr. The nature of the fructification of this alga had not been satisfactorily cleared up, the late Prof. Fr. Schmitz maintaining that what had hitherto been regarded as the fructifying nemathecium was a parasite. His view, however, while widely accepted by algologists, was opposed by Reinke and others. Specimens of this alga, richly *fruited*, were placed alone in a glass jar, in sterilised sea-water, on the 1st February, 1896, and after two months (30th March) a very great number of germinated spores, in the shape of small discs, were found on the sides and bottom of the glass jar. The structure and appearance of these discs was such as to practically leave no doubt that they were early stages in the growth of *Ahnfeltia plicata*, and not of a parasite. As a result of this experiment, I am strongly of opinion that Prof. Fr. Schmitz's genus *Sterrocolax* will have to be sunk, and in this view I am supported by Mr. Batters. Unfortunately, owing to the difficulties of cultivation, I did not succeed in getting the culture beyond the disc stage. As the Royal Society has generously renewed the grant by the aid of which these investigations are being carried on, I hope to repeat the culture, with more success, when the season comes round again.

As part of my investigation, I am studying the attaching discs of the red sea-weeds, or Florideæ, in order to ascertain to what extent the conditions found in *Dumontia filiformis*, Grev., prevail in other species. So far I have found no other alga which shows a mode of development, from an attaching disc, similar to that described for *D. filiformis*. Cf. "On the Development of the Filamentous Thallus of *Dumontia Filiformis*," *Journal of the Linnean Society*—Botany, vol. xxx. A large number of red sea-weeds (*e.g.* Gigartina, Polyides, Stennogramme, Phyllophora, Ahnfeltia) are connected with their attaching discs by a simple parenchyma-like tissue; one or two forms present different and interesting features in the development of the vertical frond from the attaching base, and when their structure is more fully worked out will, in due course, be described and published, but these conditions in no wise resemble what was found to be the case in *D. filiformis*.

The germination of the spores of *Glœosiphonia capillaris* has yielded interesting results with regard to the mode of formation of the attaching disc. On germinating, the spore sends out a few-celled filament, which by the radiate branching of one or two of the cells forms a well-marked disc.

My friend Mr. Edw. Batters has continued to give me his invaluable aid in the identification of species, &c. Two or three of the above finds are entirely due to him (*e.g. Peyssonelia rupestris*, Crn., *Lithothamnion Strömfeltii*, Foslie), he having recognised them in material forwarded from the Laboratory.

The new species and forms will be described by Mr. Batters in the forthcoming number of the *Journal of Botany* (*i.e.* in September).

SUPPLEMENT TO

Report on the Sponge Fishery of Florida and the Artificial Culture of Sponges.*

By

E. J. Allen, B.Sc.

Hon. Secretary of the Marine Biological Association, and Director of Plymouth Laboratory.

Since the Report on the subject of the Artificial Culture of Sponges was published, some further information of importance relating to the subject has been courteously supplied by the Acting Commissioner of the United States Commission of Fish and Fisheries. This information is in the form of a letter to the United States Commission from Mr. Ralph M. Monroe, of Cocoanut Grove, Biscayne Bay, Florida, to whom the Acting Commissioner refers as "an intelligent and energetic man, whose statements, we think, can be given entire credence," wherein this gentleman gives a detailed account of some experiments conducted by himself at Biscayne Bay, during the years 1889, 1890 and 1891.

The letter, which is published by permission of the Acting Commissioner, is as follows:—

"Cocoanut Grove, Dade Co., Florida,
March 20*th*, 1895.

"U. S. Fish Commission, Washington, D. C.

"Dear Sirs,—Agreeably to request made by you for a brief report on my experiments in sponge culture, I am pleased to submit the following:

Having had my attention called to the possibilities of sponge culture by Mr. J. Fogarty, of Key West, a gentleman of much experience as a buyer and packer of the article, and who had a few years previously successfully grown a few samples from cuttings, I began work in the same line in November, 1889, at Biscayne Bay, a place admirably

* This Journal. Vol. iv. p. 188.

adapted to such experimenting, far more so than any other place on the coast, having a greater range of bottom from the oozy marls of the inner lagoons to the hard outer coral reef, waters of all degrees of density, from the Gulf Stream to fresh, and currents to suit. Being already well provided with a vessel, boats, sponge hooks, and water glasses, the question of suitable material for attaching to and sinking the cuttings to the bottom gave some trouble, although apparently a simple problem. Saplings of white wood which were plentiful, fairly proof against worms, and heavy enough to retain their place in strong tideways, were finally chosen. They were about 12 feet in length, with a cross piece at one end to prevent rolling over. The cuttings were fastened to them by various contrivances, wedged into holes with pegs, wires around the pole, etc., but the quickest, if possibly not the best, as it afterwards turned out, was short pieces of brass wire doubled and driven into the pole with a peculiar grooved punch, which could be done rapidly. At other stages of the experiment I used bamboo stakes, long double lines of twisted wire connected by cross pieces of white wood, with the cuttings inserted between the strands, also flat pieces of coral rock with drilled holes and wooden wedges. Galvanized iron in any form did not answer, especially wire, as it quickly corroded. Most of the first plantings were lost by its use, and I am also inclined to condemn brass wire on account of the possible poisonous effects of the salts formed on it, although some of the best results were obtained when it was used. Having prepared the sinkers and hooked up sufficient sponge for several days' work, placing them in nets hung from the side of the schooner, the process was as follows: Take the poles or other sinker material in a small boat, two kedge anchors, a small long line, and the sponge in buckets in which the water was changed every few minutes (in this connection, it has been generally understood that exposure to air and sun for even a few minutes was fatal to a sponge, and at first I was very careful in this respect: subsequently I found that several hours of such exposure did not hurt them to any extent: stagnant water, however, will kill them in a very short time), a cutting board and knife, the latter very thin and re-sharpened often, owing to the calcareous matter embedded in the sponge. Having reached the locality which was at first selected by the natural sponge growth already on it, the two kedges are let go at either end of the long line, and by hauling along this line the plantings could be kept quite regular, and when finished were marked by range stakes set up on the adjacent dry banks. The depth of water ranged from eight feet to less than one foot at low tide, at which latter depth many fine sponges are found. By the use of a water glass the plantings could be easily observed at any time without disturbing them. In cutting the sponge it was done as nearly as possible in a line with the radial circulating canals, and that each piece should have on it a part of the outer cuticle. As many were not cut this way, and lived, it may not be at all necessary. Each piece was about one inch square on top and somewhat more in length, coming to a point, averaging 25 to a sponge. In cutting care was taken not to express the natural juices or milk, and quickly attaching to the sinkers, were immediately put into the water. The poles held on an average 12 pieces placed 12 inches apart, and with one assistant I was able to plant about 200 cuttings per day. With a more suitable boat having a well to keep the sponge in, and another assistant, I could easily plant from 600 to 800.

This work was continued with intervals from November, 1889, until June 11, 1891, with various results, under all the conditions of bottom, depth, current, etc. With but few exceptions, the sponge survived the cutting process and began a good healthy growth, to be afterwards lost or destroyed in various ways. In many cases, notably one lot planted back of Elliott's Key in 4 feet of water on hard bottom, 75 per cent. lived and in 6 months had doubled in size; these were mostly taken up before reaching maturity, as a gale would have swept them away, and did so with those that were left. Mature specimens were gotten from many of the other plantings, but the average loss from defective fastenings and other causes was greater. The results can be summed up as follows:

Material for anchoring cuttings: While very many things other than those used suggested themselves in the progress of the work, I kept strictly within the limits of what was economic and practical, therefore poles and stone seemed best suited, preferably the former arranged so as to be elevated a short distance above the bottom to avoid smothering with silt, and to avoid the coral, etc., which is apt to grow in with the sponge. Fastenings of just the right character have yet to be invented.

Location: Anywhere within the bays and lagoons free from heavy sea, too strong current, and too much fresh water, and in moderate depths for easy handling and observation.

Growth: This is faster in strong currents, but shape is apt to be poor and quality harsh. This point, however, is not fully determined. Under favourable conditions the cuttings doubled their size in 6 months; consequently, 18 months to 2 years will produce marketable sponge. The sheepswool was the only one of the useful kinds experimented on, although a few cuttings of velvet, grass, and others, seemed to thrive and do equally well. It is quite possible that with State protection to the planters, and better methods to be determined upon by further experiment, sponge culture might be quite profitable. My belief is, gained in oyster culture from spawn, that a similar method with sponge will eventually prove the correct one, but until more is known of sponge biology it would be useless to suggest methods, notwithstanding the fact that several points in connection with it have been to my mind quite clearly demonstrated. Unfortunately, having had to turn my attention to matters of more immediate pecuniary return, the subject has remained in abeyance.

Very respectfully yours,

(Signed) RALPH M. MONROE."

Variations and Relationship of the Flounder and the Plaice.*

By

F. B. Stead, B.A.

THERE can be no question of the importance of the subjects treated of in this paper; and the results are certainly such as to attract attention. This fact makes it all the more disappointing that the author's method is not calculated to inspire confidence in the accuracy of his conclusions. Before attempting to justify this statement, we may give a brief account of the paper as it stands.

After giving an extensive bibliography, the author passes on in his second chapter to a statement of the method of the investigation, and of the notation by which he finds it necessary to state his results. In the next chapter a table is given showing the extent of variation of particular characters in the species considered, and the degree in which the variations of these same characters in both forms may coincide. The influence of sex and age, and the character and development of the scales, is next treated of, and the following chapter is devoted to a statement of the differences which obtain between the different "local forms" in the North Sea and the Baltic. The rest of the paper is taken up with a consideration of the relations between the local forms and the species, an account of *Pleuronectes pseudoflesus*, certain morphological and biological observations, and a summary of results. We may now consider the more important parts of this paper in detail,

The method of investigation consisted in examining "a large number" of specimens of each species in respect of no less than thirty-six characters. Of these eleven were finally selected as sufficing to distinguish the species one from another, as well as the individual forms of each species from different localities.

* "Variation und Verwandschaft von. Pl. flesus L. und Pl. platessa L., untersucht mittelst der Heincke'schen Methode," von Georg Duncker. *Wiss. Meeresuntersuch herausgegeben von d. Komm. zur Wiss. Untersuch d. deutschen Meere in Kiel. Heft. 2, 1896.*

These characters were the number of vertebræ in the caudal peduncle and in the tail, the number of vertebræ which have no median hæmapophysis, and the total number of vertebræ; the number of fin rays in the dorsal and anal fins; the length of the caudal peduncle, and its mean height; the total length of the body without the caudal fin; the length of the head on the ocular side; and the number of branchiostegal rays. In order to eliminate small errors of measurement, such as those which result from the shrinkage of specimens which have been preserved in spirit, and to give at the same time a clearer expression of the main facts of variation, the total range of variation in respect of each particular character was legitimately divided into a small number of arbitrarily selected divisions. Into one of these divisions a number of individuals, all varying slightly from one another, would then fall; and the individuals in question would be regarded as identical in respect of the particular character examined. The author has, however, considered it necessary to adopt a notation to represent the "variation degrees" of each character, which makes his paper by no means easy to read. The several characters of particular individuals are represented by formulæ which the reader has to interpret by reference to the chapter on the method employed, whenever they occur. Thus we are told that the "Extreme Flounder form" has characters represented by the formula $5+19+9=33.\ \alpha\ \alpha\ \delta\ \alpha$ (1).

Having explained his method, the author gives in his next chapter a table, in which the limits of variation for each particular character in the two species considered are indicated.

In two forms so closely allied as the plaice and the flounder, a considerable part of the entire range of variation for any character is often common to the two species.

The table given shows in an interesting manner the degree to which the variation ranges of the several characters are distinct in the two species. Thus the number of fin rays in the dorsal fin varies from 51–65 in the flounder, and from 61–80 in the plaice.

The total range of variation is 30, and of these 30 possible variations there are 5 which are common to both species. This fact is expressed by saying that the percentage of variation common to the two species is 17 per cent. It is noteworthy that in respect of the depth of the body and the length of the head—the measurements in each case being expressed as percentages of the body length—there is no difference in the ranges of variation for the two species.

Our author next deals with the influence of age and sex. This part of the subject appears to us to be somewhat inadequately treated. In dealing with local forms, the author states that he examined exclusively "the grown up" specimens ("erwachsenen materials") without defining the term. An examination of the tables given for plaice reveals the fact that the majority of the specimens examined varied in length from 20–30 cms. (about 8–12 in.). To assume that all these individuals were "grown up," and that the influence of age need not therefore be considered, is to assume what appears to us to require proof. Our author himself points out that the influence of age might be such as to lead an observer to erroneous conclusions with regard to the influence of locality. But he neither investigates the relation of differences in age to any particular character, nor does he examine for each locality a sufficient number of individuals of about the same size to render it probable that the differences due to variation in age may be safely left out of consideration. It is clear that if a sufficiently large number of forms of the same size were examined, the characters for fishes from each locality might be considered in relation to the most probable age for that size. But even so, the influence of the locality on the rate of growth would have to be determined.

With regard to the influence of sex, our author states that in both species the females are always broader, and have longer heads than the males. In the males the number of vertebræ is somewhat smaller than in the females.

The subject of the development of scales in the two species is next considered. To this we would draw special attention, as it is in respect of the character of the scales that the two species differ most strikingly from one another, and the author's observations on the point are distinctly interesting. It is pointed out, that in both species cycloid scales begin to develop (when the fish is 1·5–2·0 cms. long) over the whole surface of the body, at the bases of the caudal fin rays, on the cheeks and on the præoperculum. The plaice develops these scales on the ocular side along the inside rays of the dorsal and anal fins, and at the bases of the pectoral and ventral fins. The scales lie embedded in the skin, separated for the most part from one another, and it is only in particular parts, for instance the caudal peduncle on the ocular side, that they overlap. In the female plaice, development of scales rarely proceeds beyond this stage; in the male, changes may occur after maturity has been reached, but these changes only consist in a transformation of the cycloid scales into the ctenoid condition. In the flounder, on the other hand, the cycloid scales become transformed in various parts of the body into a ctenoid, and even more complicated condition, while the fish is still only 2–3 cms. long.

The change of a cycloid into a ctenoid scale proceeds in the following manner:—The posterior edge of the scale becomes raised out of the enclosing epithelium, and a layer of hard transparent substance bearing spines is laid down over the surface of the scale. This layer, which is divided presumably from the epithelium, travels forwards over the surface to its anterior edge, and spreads over part of the under surface posteriorly. When this process is complete the scale is said to have reached the *Dorn-Stadium.*

In the next chapter the author deals with the different local forms of the plaice and flounder from different localities in the North Sea and the Baltic. We do not propose to give a detailed statement of his conclusions, because it appears to us that the evidence on which these are based is quite insufficient. Taking the first locality dealt with as an example, we may note that the author diagnoses 20 male and 8 female flounders. He then takes the most common measure (in 28 individuals) for each character considered, and writes a formula which he calls *Die Mittelformel für die Königsberge Form.* Further, a table is appended in which the frequencies of the several variations of each character in the individuals examined is expressed in percentages of the total number of individuals. Thus we are informed that *55 per cent. of the 20* male flounders from Königsberg have 36 vertebræ.

It appears to us that little reliance can be placed on conclusions which are drawn from an examination of so small a number of individuals: and it is simply misleading to express the results of such examination in percentages, when fewer even than a hundred individuals have been examined.

The author proceeds to summarise his results by giving two formulæ, expressing the characters of Baltic and North Sea flounders. We are not altogether sure what meaning the author attaches to these generalised formulæ. The formulæ, assuming the results obtained for the separate localities to be accurate, express the most common measurements of the several characters in all the individuals examined from the Baltic and the North Sea, and they may be said to show how in a general way the flounders from these two regions differ from one another in respect to each of the several characters considered. But it would, we think, be a mistake to take these formulæ as expressing the *combined* characters of the ideal form which the environmental forces were tending to produce in these seas. If it is desired to show the direction in which evolution is tending to transform these populations, account must be taken of the facts of correlation. In a paper on certain correlated variations in *Carcinus mœnas,** it has been pointed out by Weldon that before we can estimate the changes at present going on in a race or species, we must know, among other things, (*a*) the percentage of animals which exhibit a given amount of abnormality with regard to a particular character, and (*b*) the degree of abnormality of other organs, which accompanies a given abnormality of one. The *ideal form* of which

* Weldon. *Proc. Roy. Soc.*, vol 54., p. 318.

we spoke above is not to be got at by striking an average for each of the separate characters examined in the individuals from the region in question, but rather by determining not merely the amount of any abnormality, but also the degree to which it is associated with other abnormalities. We think we are right in saying that the laws of correlation do limit, and to some extent determine, the directions which evolution may take. In dealing with local forms, these considerations ought not to be ignored.

We may make our point of view clearer by reference to the formulæ given by our author, which denote what he calls the "extreme flounder form," or the "extreme plaice form." These formulæ are arrived at by taking the extreme variations of the several characters in the flounder and the plaice, contrasting them in this way as much as possible. The formulæ thus obtained represent the sum of a number of separate possibilities; but it by no means follows that the several extreme characters, which are separately possible, are possible in combination with one another in a single individual, and, in point of fact, as an examination of the tables shows, there is not a single instance of either of these extreme forms among the individuals examined by the author.

Our author having, as the result of his investigation into the local forms, taken up the position that the relationship between the two species in the Baltic is closer than in the North Sea, finds support for this view in the existence of an intermediate form which inhabits the south-western part of the Baltic, and which was first described by Gottsche as a variety of the plaice, and named *Pleuronectes pseudoflesus*. This form differs from the flounder in having cycloid scales on its "blind side," and the ctenoid scales of the plaice on its ocular side. It differs, however, from the latter species, and approaches the former in having rows of scales on its lateral line, and on the bases of the dorsal and anal fin rays, which are more highly developed than the ctenoid scales, and represent, in fact, a stage in the development of the scales which is characteristic of the flounder. The question arises, whether it is an intermediate form or a hybrid. On the one hand, the fertility of the fishes would seem to point to the former hypothesis; on the other, the mingling of the specific characters (of the flounder and the plaice), and the rarity of its appearance, would seem to support the latter. Our author inclines to support the latter view, in opposition to Möbius and Heincke, "ohne dass ich einen wissenschaftlichen grund hierfür anzugeben vermöchte."

A form has been described by Ekström and Smitt which is also intermediate between the flounder and the plaice, and differs very slightly from *Pleuronectes pseudoflesus*. This form, to which the name *Pl. glacialis* has been given, is found on the western part of the north coast of North America, and on the north coasts of Asia and Europe.

Attention may now be drawn to the hypothesis concerning the origin of these closely allied forms, which the author tentatively puts forward. It is pointed out in the first place that the Baltic may be considered intermediate between the North Sea and the Arctic Ocean, as regards the populations it contains. Further, the Baltic plaice, which differ from those of the North Sea in the smaller number of their vertebræ and fin rays, and in the stronger and more conspicuous ctenoid scales which they possess (characters which may be said to be masculine), would, if these differences were intensified, come to resemble very closely the Arctic form *Pl. glacialis*. On the other hand, the flounder in the eastern part of the Baltic tends to vary in the direction of a greater number of vertebræ and fin rays, and these characters are feminine. *Pl. glacialis* may, then, be regarded as representing an extreme form of either the plaice with masculine characteristics, or the flounder whose characteristics tend to be feminine. Our author considers that of the forms under consideration, the *plaice*, judging from the rudimentary development of its scales, is the oldest; that this form was originally confined to northern latitudes; and that it wandered thence to the North Sea—without undergoing very much change; and to the northern coasts of Europe and Asia, where it gave rise to the variety *glacialis*. At the same time an immigration took place into the Baltic, through the Gulf of Bothnia, which was then open to the North, and the plaice approximated to the *glacialis* type. As a result of the influence of a mild climate, *Pl. glacialis* became transformed to a flounder-like form. This latter spread over the North Sea and the Atlantic coasts of North America, and gave rise to a number of varieties.

In the meantime the original *Pl. glacialis* of the Baltic disappeared, and this form only now remains in the more northern latitudes where it took its rise. It will be seen that this hypothesis attempts to account for the differences which obtain between the North Sea and Baltic plaice, and derives the flounder from a form like the plaice—the modern *Pl. glacialis* being regarded as representing an intermediate stage in the evolution of the flounder.

In conclusion, we may note that the author carefully refrains from discussing the causes which have given rise to the local varieties he describes. He does not even enter into the question whether the local differences arise in the ontogeny of each individual, as the result of the direct action of the environment, or whether they are inherited: in other words, he does not, so far as we can make out, commit himself as to the real nature of the local varieties—whether they are to be regarded as distinct races or no. He says not a word of Natural Selection or of Lamarckian factors. We are very far from being disposed to complain of these omissions.

In his concluding paragraph the author justifies his research by showing that it points to this important fact, namely, that the morphology of an organism is not wholly dependent on internal formative forces—*e.g.*, Heredity, and Variation due to internal causes—but is also directly influenced in a determinate manner by external, chemical, and physical forces. The author, unless we are much mistaken, is not here concerned with the causes of evolution: he is merely pointing to the fact that every individual is continually subject to external influences, which must have an effect on its structure, whether characters so acquired are inherited or not.

And these external influences may act directly to produce certain modifications in the individual during its lifetime, or indirectly in determining the incidence of selection, or in both of these ways. Leaving out, for the sake of argument, the possibility of inheritance of acquired characters, the external conditions must still be considered of the greatest import—a fact which will be appreciated when it is remembered that an individual cannot be rightly regarded as a naked bundle of characters transmitted from its parents, but as an organism endowed with certain inherited tendencies, and reacting during life to the conditions of its environment. There can be no question, then, of the value of research which is concerned with the examination of the effects of external conditions. And this makes us regret all the more that the author was not as careful in establishing his facts on a sure basis as he is cautious in expressing his opinion on the theoretical aspects of the subject.

Director's Report.

As I was able to announce in a *postscript* to my Report in the last number of the Journal, the Association has secured a small steam fishing yacht, which has already proved exceedingly useful in carrying on the work of the Laboratory. Towards the £600 which was paid for the vessel, a little over £500 has now been subscribed. It is important that the remainder of the sum should be forthcoming, so that it may not be necessary to draw upon our small reserve fund for this purpose.

The number of workers who have visited the Laboratory for the purpose of conducting independent researches has been maintained; and at the same time the arrangement by which students are admitted to the Laboratory for the purpose of study, rather than of research, has been taken advantage of by a much larger number of students than was anticipated.

The following is a list of Naturalists who have occupied research tables, and of the subjects which have engaged their attention:

Brebner, G., September 5th, 1895 (*Marine Algæ*).
Riches, T. H., B.A., January 13th (*Development of Nemertines*).
Garstang, W., M.A., March 23rd to May 1st, July 22nd (*Marine Bionomics*).
Church, A. H., B.A., April 1st to April 25th, July 8th (*Marine Algæ*).
Mac Munn, C. A., June 3rd to 17th (*Blood of Fishes and Invertebrates*).
Cleve, P. T., Ph.D., July 2nd to 7th (*Diatoms*).
Watasé, S., Ph.D., July 3rd to 8th (*Phosphorescence of Marine Animals*).
Weldon, W. F. R., M.A., July 7th (*Variation of Crabs*).
Colcutt, Miss M. C., July 15th (*Hydroids*).
Beer, T., Ph.D., July 27th (*Sense Organs of Crustacea*).
Scott, S. D., B.A., July 28th (*Ascidians*).
Barnard, J. E., August 4th (*Phosphorescent Bacteria*).

In addition to these, *twenty* students have attended the classes conducted by Mr. Garstang. There is every reason to believe that such classes will become a regular feature of the work of the Laboratory, and a useful adjunct to its activities in other directions. Students attending the classes have the opportunity of taking part in the regular collecting work of the Association, and are thus enabled to obtain a good knowledge of marine animals under their natural conditions.

The book which Mr. J. T. Cunningham has recently been preparing, on *The Marketable Marine Fishes of the British Islands*, is to be published for the Association by Messrs. Macmillan and Co., and will appear at an early date. This work, which it is hoped will meet a long-felt want, has been prepared with a view to bringing before the general reader, in a connected narrative form, the information contained in the numerous technical memoirs, which have appeared during the last few years, dealing with marine fishes, their habits, and modes of development. The book is liberally illustrated with process blocks, and should prove exceptionally useful to those who are interested in fishery questions, either for profit or from the legislative point of view.

E. J. ALLEN.

August, 1896.

Marine Biological Association of the United Kingdom.

Report of the Council, 1895–96.

The Council.

Four ordinary and two special meetings of the Council have been held during the year. The average attendance at the meetings has been 9·5. A sub-committee of the Council visited and inspected the Plymouth Laboratory on June 6th.

No vacancy has occurred on the Council itself during the year, but the Council has to deplore the loss of Prof. Huxley, the first President, to whose efforts the successful launching of the Association, and the assistance which it has received from the Government, the City Companies, and other public bodies, were largely due.

The Council has to again thank the Royal Society and the Linnean Society for permitting the meetings of the Association to be held in their rooms.

The Plymouth Laboratory.

Considerable expense has been incurred during the year in repairing the engines and pumps which supply sea-water to the Aquarium. The fact that a circulation has to be continuously maintained causes considerable wear and tear, and constant repairs are necessary to ensure against the possibility of a breakdown. The buildings, fittings, and machinery of the Laboratory are in good condition.

The Boats.

For the first nine months of the year the ordinary collecting work of the Laboratory was done by the sailing-boat *Anton Dohrn*, supplemented from time to time by hired steam tugs. For the fishery investigations conducted by Mr. Stead a small sailing trawler was hired.

The steam-launch *Pansy* has been sold to her former owner, and in February last the Association purchased the steam fishing yacht *Busy Bee* from Mr. Treffry, of Fowey. This boat, which is 60 feet long, and has a gross tonnage of 22·5, is well adapted to the ordinary work of the Association, and is as large a vessel as it would be possible to maintain on our present income. The vessel is in good condition, and it is hoped that she may do good work for the Association for some years to come.

Museum.

Progress has been made in the re-arrangement of the type collection of the local fauna for the Museum, and several of the more important groups are almost complete. The herbarium has also been largely augmented during the year, and should prove valuable to botanists who visit the Laboratory.

The Staff.

The only alteration which has taken place in the staff since the last Annual Meeting has been the appointment of Mr. T. V. Hodgson to the post of Director's Assistant.

Mr. Cunningham still continues to devote himself to investigations connected with the North Sea fisheries, though the Council have to regret that up to the present no special donation has been forthcoming to provide for the continuation of this work.

It is in the direction of an increase in the number of naturalists employed by the Association that we must look for future developments of our work. Now that a more suitable steamboat has been procured, the Laboratory and its appliances may be regarded as sufficiently complete to allow of a much larger amount of useful work being turned out, if a sufficient number of workers can be engaged for lengthened periods.

The Library.

Although that portion of the Library which comprises the literature relating to Sea Fisheries may be regarded as fairly complete, a considerable sum of money will have to be spent before an equally favourable report can be made of the supply of literature dealing with scientific zoology and botany. Not only are we unable, with our present income, to procure regularly many of the important journals, which should find a place in a Library such as ours, but back numbers of journals to which we now subscribe are in many cases deficient. Through the kindness of Sir William Flower, one such defect has been remedied during the year by the completion of our set of the Philosophical Transactions of the Royal Society from the year 1866.

The thanks of the Council are due to the Royal Society, the Zoological Society, the Royal Microscopical Society, and numerous other societies and individuals, at home and abroad, for copies of their publications, by gift or exchange, which have been received.

General Report.

Mr. Cunningham's memoir on the natural history of marketable food fishes, to which reference was made in the last Report, having assumed a larger and more complete form than was at first intended, it has been decided to issue it as a book. The work will be very fully illustrated, and arrangements have been made by which it will be published for the Association by Messrs. Macmillan and Co.

During the summer of last year Mr. Cunningham, in addition to a prolonged stay at Grimsby, visited Scarborough, Lowestoft, and other fishing centres on the East Coast, and by thus extending the field of observation, was able to supplement the work done by Mr. Holt in some important particulars.

Mr. Stead has been carrying out trawling experiments in the Bays on the South Coast of Devon, which are at present closed to trawlers, with a view to determining the nature of the fish populations which they contain at various times of the year.

The ordinary dredging and trawling work carried on from the Plymouth Laboratory has been extended to the deeper water between the Eddystone Rocks and Start Point, and material is being collected for the compilation of a detailed chart of the various grounds in this area, showing the nature of the bottom and the kinds and proportions of the inhabitants at each spot.

Occupation of Tables.

The following naturalists engaged in research work have occupied tables in the Plymouth Laboratory during the year:

P. Barthels, Ph.D., Bonn (Echinodermata).
W. I. Beaumont, B.A., Cambridge (Faunistic Researches).
A. Bethe, Ph.D., Berlin (Nervous System of Crustacea).
G. Bidder, M.A., Cambridge (Sponges).
G. Brebner, Royal College of Science (Marine Algæ).
E. T. Browne, B.A., University College, London (Medusae).
A. H. Church, B.A., Oxford (Marine Algæ).
W. Garstang, M.A., Oxford (Marine Bionomics).
J. D. Gilchrist, B.Sc. Ph.D., Edinburgh (Nervous System of Mollusca).
T. V. Hodgson, Mason College (Amphipoda).
T. H. Riches, B.A., Cambridge (Development of Nemertines).
T. H. Taylor, M.A., Yorkshire College, Leeds (Polyzoa).
W. F. R. Weldon, M.A., University College, London (Variation of Crabs).

An important development of the usefulness of the Laboratory has been made by the establishment of vacation classes for advanced university students. Courses of study in Marine Biology have been conducted by Mr. W. Garstang, who was for many years a member of the Association's staff. Eighteen students have taken advantage of this arrangement during the year, the class held at Easter numbering fifteen.

To accommodate this class a room on the ground-floor of the east block of the building has been specially fitted up, so that research workers in the large laboratory are in no way interfered with. It is believed that by thus arousing interest in marine investigations before the students have completed their university course, many of them will be likely to subsequently use the Laboratory for the purpose of scientific research.

Amongst the papers, either wholly or in part the outcome of work done in the Laboratory, which have appeared elsewhere than in the Journal of the Association, are the following:

ALLEN, E. J.—*Studies on the Nervous System of Crustacea.* Quart. Journ. Micr. Sci. xxxix. p. 33.

BARTHELS, P.—*Notiz über die Excretion der Holothurien.* Zool. Anzeiger, No. 492. 1895.

BIDDER, GEORGE.—*The Collar-cells of Heterocoela.* Quart. Journ. Micr. Sci. xxxviii. p. 9.

BROWNE, E. T.—*On the Variation of Haliclystus octoradiatus.* Quart. Journ. Micr. Sci. xxxviii. p. 1.

GARSTANG, W.—*Budding in Tunicata.* Science Progress, iii. March, 1895.

GARSTANG, W.—*Outlines of a new Classification of the Tunicata.* British Association. Ipswich. 1895.

HICKSON, S. J.—*The Anatomy of Alcyonium digitatum.* Quart. Journ. Micr. Sci. xxxvii. p. 343.

MACBRIDE, E. W.—*The Development of Asterina gibbosa.* Quart. Journ. Micr. Sci. xxxviii. p. 339.

NUTTING, C. C.—*Notes on the Reproduction of Plumularian Hydroids.* Amer. Naturalist, Nov., 1895, p. 966.

Donations and Receipts.

The Receipts for the year include the annual grants from H.M. Treasury (£1000) and the Worshipful Company of Fishmongers (£400), a special donation from Mr. T. H. Riches (£30), annual subscriptions (£153), rent of tables in the Laboratory (£89), sale of specimens (£256), and admission to the Aquarium (£76). In addition to these amounts, the following sums have been promised towards the £600 required for the purchase of the steam yacht *Busy Bee:*

Fishmongers' Company	£105
The Royal Society	£100
J. P. Thomasson, Esq.	£100
Drapers' Company	£52 10s.
Grocers' ,, ...	£50
Mercers' ,, ...	£26 5s.
Goldsmiths' ,, ...	£20
Earl Ducie	£10
Sir Henry Thompson	£10
W. I. Beaumont, Esq. . . .	£1 1s.

making a total of £474 16s. for this purpose.

The total receipts for the year from all sources amount to £2419.

Vice-Presidents, Officers, and Council.

The following is the list of gentlemen proposed by the Council for election for the year 1896–97 :—

President.

Prof. E. RAY LANKESTER, LL.D., F.R.S.

Vice-Presidents.

The Duke of ARGYLL, K.G., K.T., F.R.S.
The Duke of ABERCORN, K.G., C.B.
The Earl of ST. GERMANS.
The Earl of MORLEY.
The Earl of DUCIE, F.R.S.
Lord REVELSTOKE.
The Right Hon. Lord TWEEDMOUTH.
Lord WALSINGHAM, F.R.S.
The Right Hon. A. J. BALFOUR, M.P., F.R.S.
The Right Hon. JOSEPH CHAMBERLAIN, M.P.
The Right Hon. Sir JOHN LUBBOCK, Bart., M.P., F.R.S.
Prof. G. J. ALLMAN, F.R.S.
Sir EDWARD BIRKBECK, Bart., M.P.
Sir WM. FLOWER, K.C.B., F.R.S.
A. C. L. GÜNTHER, Esq., F.R.S.
Prof. ALFRED NEWTON, F.R.S.
Rev. Canon NORMAN, D.C.L., F.R.S.
Sir HENRY THOMPSON.
Rear-Admiral WHARTON, C.B., F.R.S.

Elected Members.

F. E. BEDDARD, Esq., F.R.S.
Prof. F. JEFFREY BELL, F.Z.S.
G. C. BOURNE, Esq., F.L.S.
Sir JOHN EVANS, K.C.B., Treas. R.S.
G. HERBERT FOWLER, Esq.
S. F. HARMER, Esq.
Prof. W. A. HERDMAN, F.R.S.
Prof. S. J. HICKSON, F.R.S.
J. J. LISTER, Esq.
JOHN MURRAY, Esq., F.R.S.
P. L. SCLATER, Esq., F.R.S., Sec. Z.S.
D. H. SCOTT, Esq., F.R.S.
Prof. CHARLES STEWART, F.R.S.
Prof. W. F. R. WELDON, F.R.S.

Hon. Treasurer.

E. L. BECKWITH, Esq.

Hon. Secretary.

E. J. ALLEN, Esq., The Laboratory, Citadel Hill, Plymouth.

The following Governors are also members of the Council :—

ROBERT BAYLY, Esq.
J. P. THOMASSON, Esq.
THE PRIME WARDEN OF THE FISHMONGERS' COMPANY.
E. L. BECKWITH, Esq. (Fishmongers' Company).
Prof. BURDON SANDERSON, F.R.S. (Oxford University).
Prof. MICHAEL FOSTER, F.R.S. (Cambridge University).
Sir WILLIAM FLOWER, K.C.B., F.R.S. (Brit. Assoc. for Advmnt. of Science).

Receipts.	£	s.	d.	£	s.	d.
To Balance from last year, being Cash in Bank and in hand (General Fund and Bait Investigation Fund)				456	12	2
,, H.M. Treasury				1000	0	0
,, Fishmongers' Company				400	0	0
,, Special Donations—						
Fishmongers' Company	105	0	0			
J. P. Thomasson, Esq.	100	0	0			
Drapers' Company	52	10	0			
Mercers' Company	26	5	0			
T. H. Riches	30	0	0			
Goldsmiths' Company	20	0	0			
Sir H. Thompson	10	0	0			
Earl of Ducie	10	0	0			
J. C. Chapman	2	2	0			
G. P. Bidder	0	10	6			
				356	7	6
,, Annual Subscriptions				153	5	0
,, Rent of Tables £ 89 7 0						
,, Sale of Specimens 256 10 4						
,, Sale of Journal 20 19 9						
	366	17	1			
,, Sale of Launch *Pansy*	40	0	0			
,, Admission to Tank Room	76	8	4			
,, Interest on Investment	25	18	2			
				509	3	7
,, Balance forward, being overdraft at Bank, less Cash in hand				201	10	3
				£3076	18	6

Expenditure.	£	s.	d.	£	s.	d.
By Salaries and Wages—						
Director	200	0	0			
,, allowance for Assistant	100	16	8			
Naturalist	250	0	0			
Assistant Naturalist	125	0	0			
Wages, &c.	439	17	3			
				1115	13	11
,, Stationery, Office Printing, Postage, &c.				178	3	9
,, Printing Journal	138	2	1			
,, Illustrating do.	4	18	9			
				143	0	10
,, Purchase of Steamer *Busy Bee*				605	0	0
,, Sundry Expenses—						
Gas, Water, Coal, Oil, &c. £107 9 2						
Coal and Water for Steam Launch 7 15 1						
	115	4	3			
Insurance of Steam Launch	31	13	7			
Stocking Tanks, Feeding, &c.	73	6	9			
Glass, Chemicals, Apparatus, &c. £223 12 7						
Less Sales of Glass 9 9 9						
	214	2	10			
Maintenance and Renewals of Buildings, Boats, & Nets £327 5 0						
Less Sales of Nets 0 3 0						
	327	2	0			
Rates and Taxes	7	12	10			
Boat Hire	90	2	7			
Travelling Expenses	34	7	9			
Expenses of Exhibition of Specimens	5	8	4			
Library	74	9	3			
North Sea Investigation	61	9	10			
				1035	0	0
				£3076	18	6

Investment held 31st May, 1896—
£670 Forth Bridge Railway 4 % Guaranteed Stock, at 125 = £837 10 0

Examined and found correct, (Signed) Stephen E. Spring Rice, Edwin Waterhouse, S. F. Harmer, C. Stewart, *Auditors.*

22nd June, 1896.

LIST

OF

Governors, Founders, and Members.

1ST AUGUST, 1896.

I.—Governors.

The British Association for the Advancement of Science, 22, *Albemarle Street, W.* £500
The University of Cambridge..... £500
The Worshipful Company of Clothworkers, 41, *Mincing Lane, E.C.* £500
The Worshipful Company of Fishmongers, *London Bridge* £3905
The University of Oxford £500
Bayly, Robert, *Torr Grove, Plymouth* £1000
Bayly, John (late), *Seven Trees, Plymouth* £600
Thomasson, J. P., *Woodside, near Bolton* £950

II.—Founders.

* Member of Council. † Vice-President. ‡ President.

1884 The Corporation of the City of London £210
1888 The Worshipful Company of Drapers, *Drapers' Hall, E.C.* £315
1884 The Worshipful Company of Mercers, *Mercers' Hall, Cheapside* ......£341 5*s.*
1884 The Worshipful Company of Goldsmiths, *Goldsmiths' Hall, E.C.*..... £100
1889 The Worshipful Company of Grocers, *Poultry, E.C.* £120
1884 The Royal Microscopical Society, 20, *Hanover Square, W*..... £100
1884 The Royal Society, *Burlington House, Piccadilly, W.* £350
1884 The Zoological Society, 3, *Hanover Square, W*..... £100
1884 Bulteel, Thos., *Radford, Plymouth* £100
1884 Burdett-Coutts, W. L. A. Bartlett, 1, *Stratton Street, Piccadilly, W*.... £100
1888 Bury, Henry, M.A., *Trinity College, Cambridge*..... £100
1884 Crisp, Frank, LL.B., B.A., Treas. Linn. Soc., 17, *Throgmorton Avenue, E.C.* £100
1884 Daubeny, Captain Giles A., 30, *Cornwallis Crescent, Clifton, Bristol* ... £100
1884 Eddy, J. Ray, *The Grange, Carleton, Shipton, Yorkshire* £100
1884 Gassiott, John P., *The Culvers, Carshalton, Surrey*..... £100
‡*1884 Lankester, Prof. E. Ray, F.R.S., *University Museum, Oxford* £100

1885 Derby, the Rt. Hon. the late Earl of, K.G. £100
1884 Lister, S. Cunliffe, *Swinton Park, Masham, Yorkshire* £100
†1884 Lubbock, The Rt. Hon. Sir John, Bart., M.P., F.R.S., *High Elms, Bromley, Kent* £100
1884 Poulton, Prof. Edward B., M.A., F.R.S., *Wykeham House, Oxford* ... £100
†1889 Revelstoke, Lord, *Membland, Yealmpton, S. Devon* £100
1890 Riches, T. H., B.A., *Inglenook, Yelverton, S. Devon* £130
1884 Romanes, G. J., LL.D., F.R.S. (late) £100
†1889 Thompson, Sir Henry, 35, *Wimpole Street, W.* £110
*1887 Weldon, Prof. W. F. R., F.R.S., 30A, *Wimpole Street, W.* £100
1884 Worthington, James (late) £100

III.—Members.

ann. signifies that the Member is liable to an Annual Subscription of One Guinea.

C. signifies that he has paid a Composition Fee of Fifteen Guineas in lieu of Annual Subscription.

1884 Alger, W. H., *Manor House, Stoke, Devonport* .... *C.*
†1884 Allman, Prof. G. J., F.R.S., *Ardmore, Parkstone, Dorset*...................... £20
*1895 Allen, E. J., B.Sc., *The Laboratory, Plymouth* .... *ann.*
1889 Anderson, Dr. John, 71, *Harrington Gardens, S.W.* £20
†1884 Argyll, The Duke of, K.G., *Argyll Lodge, Kensington, W.* .... *C.*
1885 Armstrong, Lord, C.B., F.R.S., *Crag Side, Rothbury* .... *C.*
1893 Ascroft, R. L., 11, *Park Street, Lytham, Lancs*.................................. *ann.*
1892 Assheton, R., *Birnam, Cambridge* £20

1890 Badger, A. B., B.A., *Glenleigh, Oakfield Road, Balsall Heath, Birmingham* .... *ann.*
1884 Bailey, Charles, F.L.S., *Ashfield, College Road, Whalley Range, Manchester* .... *ann.*
1893 Bailey, W. E., *Porth Enys Museum, Penzance* .... *C.*
1884 Balfour, Prof. Bayley, F.R.S., *Royal Botanic Gardens, Edinburgh* ...... *C.*
1893 Bassett-Smith, P. W., Staff-Surgeon, R.N., *H.M.S. Magdala, Bombay*... *ann.*
1884 Bateson, Wm., F.R S., *St. John's College, Cambridge* .... *ann.*
1884 Bayliss, W. Maddock, B.Sc., 52, *Hamilton Terrace, London, N.W.* ...... *ann.*
1884 Bayly, Miss, *Seven Trees, Plymouth* £50
1884 Bayly, Miss Anna, *Seven Trees, Plymouth*.. £50
1884 Beaumont, W. I., *Angel Hotel, Knutsford* .... *ann.*
1885 Beck, Conrad, 68, *Cornhill, E.C.* .... *C.*
*1889 Beckwith, E. L., *The Knoll, Eastbourne* .... *ann.*
*1887 Beddard, F. E., F.R.S., *Zoological Society's Gardens, Regent's Park, N.W.* *ann.*
1884 Beddington, Alfred H., 8, *Cornwall Terrace, Regent's Park, N.W.* ...... *C.*
*1884 Bell, Prof. F. Jeffrey, 35, *Cambridge Street, Hyde Park, W.* .... *ann.*
1887 Berrington, A. D., *Board of Trade, Whitehall, S.W.* .... *ann.*
1890 Bidder, George, B.A., *Ravensbury Park, Mitcham, Surrey* .... *C.*
1885 Bignell, Geo. Carter, F.E.S., 85, *Union Street, Stonehouse, Plymouth* ... *ann.*
†1885 Birkbeck, Sir Edward, Bart., M.P., 10, *Charles Street, Berkeley Square, W.* *ann.*
1893 Bles, A. J. S., *Palm House, Higher Broughton, Manchester* .... *ann.*
1889 Bolitho, T. B., M.P., *Trewidden, Penzance*....................................... *ann.*

1884 Bompas, G. C., 121, *Westbourne Terrace, Hyde Park* .... *ann.*
1884 Bossey, Francis, M.D., *Mayfield, Redhill, Surrey* .... *ann.*
1884 Bostock, E., *Stone, Staffordshire* .... *ann.*
1890 Bourne, Prof. A. G., F.R.S., *The Presidency College, Madras* .... *ann.*
*1884 Bourne, Gilbert C., *New College, Oxford* .... *ann.*
1886 Brent, Francis, F.S.A., 6, *Tothill Avenue, Plymouth* .... *ann.*
1895 Bridge, Prof. T. W., *Mason College, Birmingham*.............................. *ann.*
1890 Brindley, H. H., M.A., *St. John's College, Cambridge* .... *ann.*
1886 Brooksbank, Mrs. M., *Leigh Place, Godstone, Surrey* .... *C.*
1884 Brown, Arthur W. W., 6, *Sussex Square, W.* .... *C.*
1893 Browne, Edward T., 141, *Uxbridge Road, N.W.*.............................. *ann.*
1893 Buchanan, Miss Florence, *The Museum, Oxford* .... *ann.*
1884 Buckton, G. B., *Weycombe, Haslemere* .... *ann.*
1886 Bullar, Miss Anna K., *Westbourne Hill, Southampton*........................ *ann.*
1887 Burd, J. S., *Cresswell, Higher Compton, Plymouth* .... *ann.*
1889 Burnard, Robert, 3, *Hillsborough, Plymouth*.................................... *ann.*

1884 Caine, H. T., 5, *Upper Wimpole Street, London, W.* .... *C.*
1884 Caine, W. S., *The Terrace, Clapham Common, S.W*........................... £21
1887 Caldwell, W. H., 12, *Harvey Road, Cambridge*................................. *C.*
1887 Carter, James, F.G.S., 30, *Petty Cury, Cambridge*........... .... *ann.*
†1884 Chamberlain, Rt. Hon. J., M.P., 40, *Princes Gardens, S.W.* .... *ann.*
1884 Christy, Thomas Howard, *Malvern House, Sydenham*........................ *ann.*
1887 Clarke, Rt. Hon. Sir E., Q.C., M.P., 5, *Essex Court, Temple, E.C*.......... £25
1884 Clay, Dr. R. H., *Windsor Villas, Plymouth* .... *ann.*
1885 Clerk, Major-Gen. H., F.R.S., 40, *St. Ermin's Mansions, Caxton Street, S.W.* £21
1886 Coates and Co., *Southside Street, Plymouth* .... *C.*
1885 Collier Bros., *Old Town Street, Plymouth* .... *C.*
1890 Cook, C. H., M.A., *Elmlea, South Stoke, Reading*.............................. *ann.*
1895 Corderoy, A., 13, *Athenæum Street, Plymouth* .... *ann.*
1889 Crossman, Major-General Sir William, K.C.M.G., *Cheswick, Northumberland*... *ann.*

1885 Darwin, Francis, F.R.S., *Wychfield, Cambridge* .... *C.*
1885 Darwin, W. E., *Ridgemount, Bassett, Southampton* £20
1889 Davies, H. R., *Treborth, Bangor* .... *ann.*
1889 Deacon, J. Barrington, 11, *Osborne Place, Plymouth* .... *ann.*
1885 Dendy, Arthur, D.Sc., *Victoria University, Melbourne* .... *ann.*
1884 Dewick, Rev. E. S., M.A., F.G.S., 26, *Oxford Square, Hyde Park, W.* .... *C.*
1885 Dixey, F. A., M.A., Oxon., *Wadham College, Oxford* ....£26 5*s.* *and* *ann.*
1890 Driesch, Hans. Ph.D., *Stazione Zoologica, Napoli*.............................. *C.*
†1889 Ducie, The Rt. Hon. the Earl of, F.R.S., *Tortworth Court, Falfield, R.S.O.* £50 15*s.*
1884 Dunning, J. W., 4, *Talbot Square, W.* ....£26 5*s.*
1884 Dyer, W. T. Thiselton, M.A., C.M.G., F.R.S., *Director of the Royal Gardens, Kew* .... *C.*

1893 Edward, Stanley, F.Z.S., *Kidbrook Lodge, Blackheath, S.E.* .... *ann.*
1891 Ellis, Hon. Evelyn, *Rosenais, Datchet, Windsor* .... *C.*
1893 Enys, John Davies, *Enys, Penryn, Cornwall*...................................... *ann.*
*1884 Evans, Sir John, D.C.L., Treas. Roy. Soc., *Nash Mills, Hemel Hempstead* £20
1885 Ewart, Prof. J. Cossar, M.D., *University, Edinburgh* £25

1884 Fayrer, Sir Joseph, Bart., M.D., F.R.S., 53, *Wimpole Street, W.* .... *ann.*
1894 Ferrier, David, M.A., M.D., F.R.S., 34, *Cavendish Square, W.* .... *ann.*
1884 Fison, Frederick W., *Greenholme, Burley-in-Wharfedale, Leeds* .... *C.*
*†1884 Flower, Sir W. H., K.C.B., F.R.S., *Director of the British Museum of Natural History, Cromwell Road, S.W.* .... *C.*
*1885 Fowler, G. Herbert, B.A., Ph.D., 12, *South Square, Gray's Inn, W.C.*... *ann.*
1884 Fox, George H., *Wodehouse Place, Falmouth* .... *ann.*
1889 Fraser, James, *Tregarthyn, Eton Avenue, N.W.* ... . *ann.*
1886 Freeman, F. F., *Abbotsfield, Tavistock, S. Devon* .... *C.*
1884 Fry, George, F.L.S., *Carlin Brae, Berwick-on-Tweed* £21
1884 Fryer, Charles E., *Board of Trade, S.W.* .... *ann.*

1892 Galton, F., F.R.S., 42, *Rutland Gate, S.W.* .... *ann.*
1885 Gaskell, W. H., F.R.S., *The Uplands, Shelford, Cambridge* .... *C.*
1885 Gaskell, E. H., *North Hill, Highgate, N.* .... *C.*
1893 Gatty, Charles Henry, LL.D., F.L.S., *Felbridge Place, East Grinstead* ... *C.*
1884 Gibson, Ernest, F.Z.S., c/o Fraser, Stoddart, and Ballingall, 16, *Castle Street, Edinburgh* .... *ann.*
1884 Gonne, William .... £26 5*s.*
1885 Gordon, Rev. J. M., *St. John's Vicarage, Redhill, Surrey* .... *ann.*
1885 Gotch, Prof. F., F.R.S., *University Museum, Oxford* .... *ann.*
1888 Goulding, F. H., *George Street, Plymouth* .... *C.*
1884 Grove, E., *Norlington, Preston, Brighton* .... *ann.*
1884 Groves, J. W., c/o Rev. J. Farmer, *Ongar Rectory, Sussex* .... *ann.*
†1884 Günther, Dr. Albert, F.R.S., 2, *Lichfield Road, Kew Gardens* .... *ann.*

1884 Haddon, Prof. Alfred C., M.A., *Innisfail Hill Road, Cambridge* .... *ann.*
1884 Halliburton, Prof. W. D., M.D., B.Sc., *King's College, Strand, W.C.* ... *ann.*
1884 Hannah, Robert, 82, *Addison Road, Kensington, W.* .... *C.*
*1885 Harmer, S. F., *King's College, Cambridge* .... *C.*
1889 Harvey, T. H., *Cattedown, Plymouth* .... *ann.*
1888 Haselwood, J. E., 3, *Lennox Place, Brighton* .... *C.*
1884 Haslam, Miss E. Rosa, *Ravenswood, Bolton* £20
1884 Hayne, C. Seale, M.P., 6, *Upper Belgrave Street, S.W.* .... *ann.*
1884 Head, J. Merrick, F.R.G.S., J.P., *Ardverness, Reigate* .... *ann.*
1884 Heape, Walter, *Heyroun, Chaucer Road, Cambridge* .... *C.*
1887 Heath, Miss A., *Yelverton* .... *ann.*
*1884 Herdman, Prof. W. A., F.R.S., *University College, Liverpool* .... *ann.*
1884 Herschel, J., Col., R.E., F.R.S., *Observatory House, Slough, Berks.* ...... *C.*
1884 Heywood, James, F.R.S., 26, *Palace Gardens, W.* .... *C.*
1889 Heywood, Mrs. E. S., *Light Oaks, Manchester* .... *C.*
*1884 Hickson, Prof. Sydney J., M.A., D.Sc., F.R.S., *Ellesmere House, Wilenslow Road, Withington, Manchester* .... *ann.*
1884 Holdsworth, E. W. H., F.L.S., F.Z.S., *Lucerne House, Dartmouth* ...... *ann.*
1893 Holt, Mrs. Vesey W., 104, *Elm Park Gardens, S.W.* .... *ann.*
1889 Howell, Mrs. F. Bullar, *Ethy, Lostwithiel* .... *ann.*
1887 Howes, Prof. G. Bond, F.L.S., *Science and Art Department, South Kensington* .... *ann.*
1884 Hudleston, W. H., M.A., F.R.S., 8, *Stanhope Gardens, South Kensington, S.W.* .... *ann.*
1885 Hurst, C. Herbert, Ph.D., *Royal College of Science, Dublin* .... *C.*

1891 Indian Museum, Calcutta, 65, *Cornhill* ... *ann.*
1888 Inskip, Capt. G. H., R.N., 22, *Torrington Place, Plymouth* ... *ann.*

1893 Jago, Edward, *Menheniot, Cornwall* ... *ann.*
1887 Jago-Trelawny, Major-Gen., F.R.G.S., *Coldrenick, Liskeard* ... *C.*
1890 Johnson, Prof. T., D.Sc., F.L.S., *Royal College of Science, Dublin* ... *ann.*
1892 Joshua, Mrs., 57, *Cadogan Square, S.W.* ... *ann.*
1894 Justen, F. W., F.Z.S., c/o Dulau and Co., 37, *Soho Square, W.* ... *ann.*

1884 Kellock, W. B., F.L.S., F.R.C.S., 94, *Stamford Hill, N.* ... *ann.*
1884 Kent, A. F. S., *Physiological Laboratory, St. Thomas's Hospital, S.W.* ... *ann.*

1885 Langley, J. N., F.R.S., *Trinity College, Cambridge* ... *C.*
1885 Lea, A. S., M.A., *Caius College, Cambridge* ... *ann.*
*1895 Lister, J. J., M.A., *St. John's College, Cambridge* ... *ann.*
1884 London, The Lord Bishop of, *The Palace, Fulham, S.W.* ... *ann.*
1888 Lopes, The Rt. Hon. Sir Massey, Bart., *Maristow, Roborough, South Devon.* ... *ann.*

1885 Macalister, Prof. A., F.R.S., *St. John's College, Cambridge* ... *ann.*
1884 Mackrell, John, *High Trees, Clapham Common, S.W.* ... *C.*
1886 MacMunn, Charles A., *Oak Leigh, Wolverhampton* ... *ann.*
1889 Makovski, Stanislaus, *Fairlawn, Red Hill* ... *ann.*
1885 Marr, J. E., M.A., *St. John's College, Cambridge* ... *C.*
1884 Mason, Philip Brookes, *Burton-on-Trent* ... *ann.*
1884 McAndrew, James J., *Lukesland, Ivybridge, South Devon* ... *ann.*
1884 McIntosh, Prof. W. C., F.R.S., 2, *Abbotsford Crescent, St. Andrews, N.B.* *C.*
1894 Meryon, Capt. J. E., R.N., *H.M.S. Katoomba, Australian Squadron* ... *ann.*
1884 Michael, Albert D., *Cadogan Mansions, Sloane Square, S.W.* ... *C.*
1885 Mitchell, P. Chalmers, B.A., 79, *Portsdown Road, Maida Vale* ... *ann.*
1885 Mocatta, F. H., 9, *Connaught Place, W.* ... *C.*
1886 Mond, Ludwig, F.R.S., 20, *Avenue Road, Regent's Park, N.W.* ... *C.*
1884 Morgan, Prof. C. Lloyd, *University College, Bristol* ... *ann.*
1891 Morgans, Thomas, *The Guildhall, Bristol* ... *ann.*
†1889 Morley, The Rt. Hon. the Earl of, 31, *Prince's Gardens, S.W.* ... *ann.*
1885 Morris, John ... £21
1885 Morrison, Alfred, 16, *Carlton House Terrace* ... £52 10s.

†1884 Newton, Prof. Alfred, M.A., F.R.S., *Magdalen College, Cambridge* ... £20
†1884 Norman, Rev. Canon, M.A., D.C.L., F.R.S., *Houghton-le-Spring Rectory, Co. Durham* ... *ann.*

1884 Ommanney, Admiral Sir Erasmus, K.C.B., F.R.S., 29, *Connaught Square, W.* ... *ann.*

1885 Paget, Sir James, Bart., F.R.S., 5, *Park Place, W.* ... *C.*
1884 Parsons, Chas. T., *Norfolk Road, Edgbaston, Birmingham* ... *ann.*
1888 Peek, Sir Henry W., Bart., F.Z.S., *Wimbledon House, Wimbledon* ... *C.*
1888 Pennsylvania, University of, *Philadelphia, U.S.A.* ... *ann.*

1885 Phillips, Chas. D. F., M.D., 10, *Henrietta Street, Cavendish Square, W.* C.
1887 Phipson, Mrs., *Cumballa Hill, Bombay* .... ann.
1895 Pinwill, Capt. *Trehane, Probus, Cornwall* .... ann.
1885 Pochin, H. D., *Bodnant Hall, Eglwysbach, Denbighshire* .... C.
1886 Power, Henry, F.R.C.S., 37A, *Great Cumberland Place, W.* .... ann.
1885 Pritchard, Prof. Urban, 26, *Wimpole Street, W.* .... ann.
1884 Pye-Smith, P. H., M.D., 54, *Harley Street, W.* .... C.

1893 Quintin, St. W. H., *Scampstone Hall, Rillington, Yorks* .... ann.

1884 Radford, Daniel, *Mount Tavy, Tavistock* .... ann.
1884 Ralli, Mrs. Stephen, 32, *Park Lane, W.* £30
1885 Ransom, W. B., *The Pavement, Nottingham* .... C.
1893 Rashleigh, E. W., *Kilmarth, Par Station, Cornwall* .... ann.
1888 Rawlings, Edward, *Richmond House, Wimbledon Common* .... ann.
1892 Robinson, Miss M., *University College, London, W.C.* .... ann.
1892 Rüffer, M.A., M.D., *Bactereological Institute, Cairo* .... ann.

1888 Scharff, Robert F., Ph.D., *Science and Art Museum, Dublin* .... ann.
*1884 Sclater, P. L., F.R.S., Sec. Zool. Soc., 3, *Hanover Square, W.* .... ann.
1884 Sclater, W. L., *The Museum, Cape Town* .... ann.
*1885 Scott, D. H., M.A., Ph.D., F.R.S., *Old Palace, Richmond, Surrey* .... C.
1884 Sedgwick, A., M.A., F.R.S., *Whitefield, Great Shelford, Cambridge* .... C.
1888 Serpell, E. W., 19, *Hill Park Crescent, Plymouth* £50
1885 Sheldon, Miss Lilian, *Oldall, Newnham College, Cambridge* .... ann.
1884 Shipley, Arthur E., M.A., *Christ's College, Cambridge* .... C.
1886 Shore, T. W., M.D., *The Warden's House, St. Bartholomew's Hospital, E.C.* .... ann.
1894 Simpson, F. C., J.P., *Maypool, Churston Ferrers, R.S.O.* .... ann.
1885 Sinclair, F. G., *New Museums, Cambridge* .... C.
1891 Sinclair, William F., 102, *Cheyne Walk, Chelsea, S.W.* .... C.
1884 Skinners, the Worshipful Company of, *Skinners' Hall, E.C.* £42
1889 Slade, Commander, E. J. Warre, *H.M.S. Cockatrice, Mediterranean Station* .... C.
1884 Sladen, W. Percy, 13, *Hyde Park Gate, S.W.* .... ann.
1893 Sorby, H. C., LL.D., F.R.S., *Broomfield, Sheffield* .... ann.
1888 Spencer, Prof. W. Baldwin, M.A., *University of Victoria, Melbourne* ... ann.
1884 Spring-Rice, S. E., C.B., 1, *Bryanston Place, Bryanston Square, W.* ... C.
*1884 Stewart, Prof. Chas., F.R.S., *Royal College of Surgeons, Lincoln's Inn Fields, W.C.* .... ann.
1884 Sutherland, The Duke of, K.G., *Stafford House, St. James', S.W.* .... C.
1894 Sykes, E. R., 3, *Gray's Inn Place, Gray's Inn, London, W.C.* .... ann.

1894 Thomas, W. F., *Bishopshalt, Hillingdon, Middlesex* .... ann.
1890 Thompson, H. F., B.A., 35, *Wimpole Street, W.* .... ann.
1884 Thornycroft, John I., *Eyot Villa, Chiswick Mall* .... ann.
1888 Thurston, Edgar, *Government Central Museum, Egmore, Madras* .... ann.
1888 Tripe, Major-General, 3, *Osborne Villas, Stoke, Devonport* .... ann.

1888 Vallentin, Rupert, 18, *Kimberley Road, Falmouth* .... ann.
1891 Vaughan, Henry, 28, *Cumberland Terrace, N.W.* .... ann.

1884 Venning, Mrs., 3, *Wingfield Villas, Stoke, Devonport* £50
1884 Vines, Professor Sydney H., M.A., D.Sc., F.R.S., *Botanical Gardens, Oxford* .... ann.

1884 Walker, Alfred O., *Nantyglyn, Colwyn Bay, N. Wales* .... ann.
1884 Walker, P. F., 36, *Princes Gardens, S.W.* .... ann.
1893 Walker, W. H., 3, *Princess Place, Plymouth* .... ann.
†1884 Walsingham, Lord, F.R.S., *Merton Hall, Thetford* £20
1890 Waterhouse, Edwin, 44, *Gresham Street, E.C.* .... ann.
1890 Were, Nicholas, 9, *Osborne Place, Plymouth* .... ann.
1895 Wickham, Rev. T. D. C., *Horsington Rectory, Templecombe, Somerset* ... ann.
1891 Wildy, A. G., 13, *Furnival's Inn, E.C.* .... ann.
1884 Wilson, Scott B., *Heather Bank, Weybridge Heath* .... C.
1884 Woodall, John W., M.A., F.G.S., *St. Nicholas House, Scarborough* ...... ann.

1891 Young, Sydney, M.D., 13, *Aberdeen Terrace, White Ladies Road, Bristol.* ann.

IV.—Associate Members.

1889 Alward, George, 11, *Hainton Street, Great Grimsby.*
1889 Caux, J. W. de, *Great Yarmouth.*
1889 Dannevig, Capt. G. M., *Arendal, Norway.*
1889 Dunn, Matthias, *Mevagissey.*
1889 Olsen, O. T., F.L.S., F.R.G.S., *Fish Dock Road, Great Grimsby.*
1889 Ridge, B. J., 3, *Gainsboro' Place, Mutley, Plymouth.*
1890 Roach, W., 4, *Gascoyne Place, Plymouth.*
1889 Shrubsole, W. H., 62, *High Street, Sheerness-on-Sea.*
1889 Sinel, Joseph, 2, *Peel Villas, Cleveland Road, Jersey.*
1890 Spencer, R. L., *L. and N.W. Depôt, Guernsey.*
1890 Wells, W., *The Aquarium, Brighton.*
1890 Wiseman, Fred., *Buckland House, Paglesham, Rochford, Essex.*

OBJECTS

OF THE

Marine Biological Association of the United Kingdom.

THE ASSOCIATION was founded at a Meeting called for the purpose in March, 1884, and held in the Rooms of the Royal Society of London.

The late Professor HUXLEY, at that time President of the Royal Society, took the chair, and amongst the speakers in support of the project were the Duke of ARGYLL, Sir LYON PLAYFAIR, Sir JOHN LUBBOCK, Sir JOSEPH HOOKER, the late Dr. CARPENTER, Dr. GÜNTHER, the late Lord DALHOUSIE, the late Professor MOSELEY, the late Mr. ROMANES, and Professor LANKESTER.

The Association owes its existence and its present satisfactory condition to a combination of scientific naturalists, and of gentlemen who, from philanthropic or practical reasons, are specially interested in the great sea fisheries of the United Kingdom. It is universally admitted that our knowledge of the habits and conditions of life of sea fishes is very small, and insufficient to enable either the practical fisherman or the Legislature to take measures calculated to ensure to the country the greatest return from the "harvest of the sea." Naturalists are, on the other hand, anxious to push further our knowledge of marine life and its conditions. Hence, the Association has erected at Plymouth a thoroughly efficient Laboratory, where naturalists may study the history of marine animals and plants in general, and where, in particular, researches on food fishes and molluscs may be carried out with the best appliances.

The Laboratory and its fittings were completed in June, 1888, at a cost of some £12,000. Since that time investigations, practical and scientific, have been constantly pursued at Plymouth. Practical investigations upon matters connected with sea-fishing are carried on under the direction of the Council; in addition, naturalists from England and from abroad have come to the Laboratory, to carry on their own independent researches, and have made valuable additions to zoological and botanical science, at the expense of a small rent, for the use of a working table in the Laboratory, and other appliances. The number of naturalists who can be employed by the Association in special investigations on fishery questions, and definitely retained for the purpose of carrying on those researches throughout the year, must depend on the funds subscribed by private individuals and public bodies for the purpose. The first charges on the revenue of the Association are the working of the sea-water circulation in the tanks, stocking the tanks with fish and feeding the latter, the payment of servants and fishermen, the hire and maintenance of fishing boats, and the salary of the Resident Director and Staff. At the commencement of this number will be found the names of the gentlemen on the staff. In no case does any one salary exceed £250.

The Association has received some £25,000, of which £11,000 has been granted by the Treasury. The annual revenue which can be at present counted on is about £1,820, of which £1,000 a year is granted by the Treasury, the remainder being principally made up in Subscriptions.

The admirable Marine Biological Laboratory at Naples, founded and directed by Dr. Dohrn, has cost about £20,000, including steam launches, &c., whilst it has an annual budget of £7,000.

The purpose of the Association is to aid at the same time both science and industry. It is national in character and constitution, and its affairs are conducted by a representative Council, by an Honorary Secretary and an Honorary Treasurer, without any charge upon its funds, so that the whole of the subscriptions and donations received are devoted absolutely to the support of the Laboratory and the prosecution of researches by aid of its appliances. The reader is referred to page 4 of the Cover for information as to membership of the Association.

CONTENTS OF NEW SERIES, Vol. IV., No. 3.

NOTICE.

The Council of the Marine Biological Association wish it to be understood that they do not accept responsibility for statements published in this Journal, excepting when those statements are contained in an official report of the Council.

TERMS OF MEMBERSHIP.

		£	s.	d.
Annual Members	per annum.	1	1	0
Life Members	Composition Fee.	15	15	0
Founders		100	0	0
Governors		500	0	0

Members of the Association have the following rights and privileges; they elect annually the Officers and Council; they receive the Journal of the Association free by post; they are admitted to view the Laboratory at Plymouth, and may introduce friends with them; they have the first claim to rent a place in the Laboratory for research, with use of tanks, boats, &c., and have access to the books in the Library at Plymouth.

All correspondence should be addressed to the Director, The Laboratory, Plymouth.