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I.

ON *PITHECANTHROPUS ERECTUS:* A TRANSITIONAL FORM BETWEEN MAN AND THE APES. By DR. EUGÈNE DUBOIS.

[Read November 20, 1895.]

In speaking of the remains, which are the subject of this Paper, I think the best way for me to take will be, first, to give an account of the circumstances attending the discovery, and further, to treat of the principal interpretations which have been given of them, including my own considerations.*

By order of the Netherlands Indian Government I conducted in Java, from 1890 to 1895, explorations for a fossil vertebrate fauna, of which already some remains had been discovered, many years ago, by Junghuhn and others, and later extensively described by Professor K. Martin, of Leiden. I found a very large quantity of remains of mammals and reptiles, for the most part derived from extinct species, which show, as might be expected, an unmistakable relation to the later Tertiary and Pleistocene faunæ of India.

The chief localities of these finds are in the southern slope of a range of low hills, the Kendengs, which extends between the residences Kediri, Madiun, and Surakarta on one side, and Rembang and Samarang on the other, in a length of about 60 miles. The area in which these vertebrate remains are abundantly found,

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* The chief substance of this Paper was contained already in a discourse which I delivered in Leiden in a session of the Second Section of the Third International Zoological Congress, on the 21st September, 1895.

in many places, may have on an average a breadth of from one to three miles. They are contained in beds of cemented volcanic tuff, consisting of clay, sand, lapilli stone, which especially, through the very general occurrence of the remains of freshwater animals, and of that fluviatile structure which English geologists call current-bedding, or false bedding, prove to be of fluviatile origin. The strata have undergone, in the whole area, considerable disturbances by folding, on account of which they have, from east to west, dips of 3° to 15° in a general southerly direction. The whole formation reaches a maximum thickness of more than 350 metres. The strata rest, unconformably, upon beds of marine marl, sand, and limestone, recently determined by Professor K. Martin to be of Pliocene age. The fossil vertebrate fauna, which they contain, is everywhere in the Kendeng, and also in other places in Java, the same, and a homogeneous one. Its age can only be judged when the description of my collection, which I intend to give in the course of a few years, shall be published. But I have studied it already a little, and it can be said, in accordance with geological circumstances, and the relations which this fauna has with the Post-Tertiary and Pleistocene vertebrate faunæ of India, that, most probably, it is young Pliocene; in no case, however, can it be younger than the oldest Pleistocene. For, whilst on the one hand the species surely belong almost exclusively to living genera—only the genus Leptobos and the sub-genera Stegodon and Hexaprotodon are extinct—and it must therefore be younger than the principal part of the Upper Miocene or Lower Pliocene Siwalik-fauna, including not a few extinct genera; on the other hand, the number of the extinct species seems to be in proportion somewhat greater than that of the Narbadá-fauna, which is put in the early Pleistocene. Further, the inclination which the strata show does not well agree with a Pleistocene age.

In August, 1891, in the neighbourhood of Trinil (in the regency of Ngawi, of the Residency Madiun), at the foot of the Kendeng, I came upon a place particularly rich in fossil bones, and found there, in that and the following year, among a great number of remains of other vertebrates, bones and teeth of a great man-like mammal, which I have named *Pithecanthropus erectus*, considering it as a link connecting together Apes and Man. These remains I held to be so important that I thought it necessary, notwithstanding the great incompleteness of my resources of comparison, to publish a provisional description in Java, especially because, through my very short reports given to the Netherland Indian Government, these finds had already raised more or less scientific discussions in Europe. It is now a year ago since my description came into the hands of the most renowned anatomists and zoologists of Europe and America; it gave occasion to so much criticism that the great importance of the remains is now unquestionable. But in the interpretation of them a very large divergence is also apparent. This divergence may be ascribed, chiefly to the very divergence of the characters of the remains, partly to the shortness of my statements. It appeared especially necessary to enter more in detail into the circumstances under which the remains were found. Concerning these circumstances, many conceptions have been formed which in no way answer to the reality. In the first place, then, let me explain the circumstances under which the remains were found.

From Trinil to Ngawi the steep banks of the Bengawan or Solo river, for an extent of 7½ miles, consist exclusively of the above-mentioned volcanic sands and lapilli, cemented into soft rocks, very much like the rocks which I saw in the Siwalik hills. The strata have in this area a general dip S. of about 5°, and are only concealed by a thin covering of vegetable soil. In these strata the Solo river has cut its channel, 12 to 15 metres deep, near Trinil. North and west of Trinil the Pliocene marl and limestone appear under them. When I first, in August, 1891, came upon the rich bone-mine of Trinil, I had already made many finds of bones at several places round about that village. All belonged to the same homogenous fauna which I had found in other parts of the Kendeng hills. The first fossil bones were a horn of a small species of deer, which is among the commonest of the fauna, a molar tooth of Stegodon, and a few other remains belonging to the same fauna. They were dug out of the rock by means of chisel and hammer, and the excavations were performed in such a manner that the rock was carefully removed in thin layers. It consists (fig. 1) from higher to lower of variously coloured sand-rock, which becomes coarser, whilst more and more lapilli occur in it, and the latter prevail in the deepest bed, about 1 metre thick, passing downward over into a conglomerate bed. Under this follows a bed of hardened blackish clay, sharply separated, which does not contain any bones. The latter in the sand-rock increase in number from higher to lower, so that the lapilli bed is the richest; the conglomerate bed, however, contains but few bones.

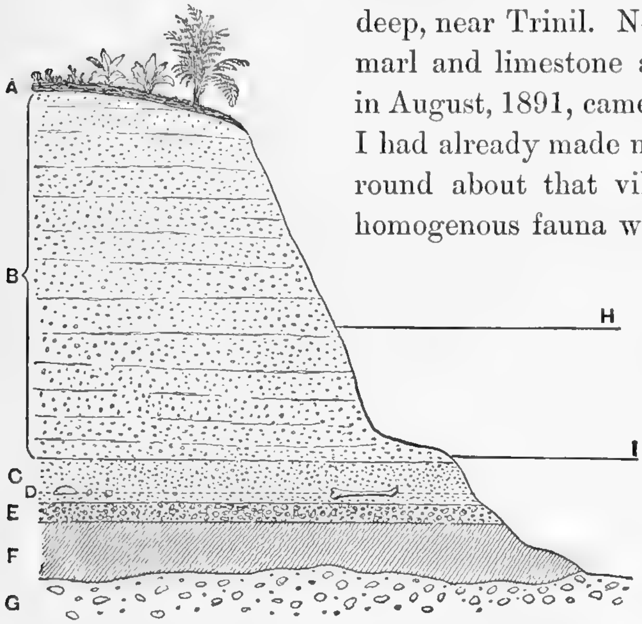

Fig. 1.—Section of the bone strata at Trinil.

A—Vegetable soil.
B—Sand-rock.
C—Bed of lapilli-rock.
D—Level in which the four remains were found.
E—Conglomerate.
F—Clay-rock
G—Marine breccia.
H—Rainy season level of river.
I—Dry season level of river.

Among hundreds of other skeleton remains, in the lapilli bed on the left bank of the river, the third molar tooth was first found in September; then, the hole having been enlarged, the cranium a month later, at about 1 metre distant from the former, but in the very same level of that bed. The species of mammals, of which remains were found in the same bed, are, for the greater part at least, extinct ones, and almost certainly none of them are at present living in Java. Among these remains we find a great number of the above-mentioned small species of Cervus, which certainly is not extant in the Malayan isles. Also many bones of Stegodon were found. One or two Bubalus species seem to be identical with Siwalik species; a Boselaphus undoubtedly differs from the known species, living and fossil. Further on there were found the extinct genus Leptobos, the genera Rhinoceros, Sus, Felis, Hyæna, and others; a Garial and a Crocodile, differing little from the existing species in India, but which cannot be classed among them.

Of the animals found in the same strata in other places, the most interesting species are a gigantic Pangolin (Manis), three times as large as the existing Javanese species, and a Hippopotamus belonging to an extinct Siwalik subgenus. Further, a Tapir and an Elephas.

The work having been brought to an end that year on account of the setting in of the rainy season, it was taken up again at the beginning of the dry season in May, 1892. A new cutting was now made in the left rocky bank, which comprised the still unfinished part of the old excavation. Thereby bones were again found in great numbers, especially in the deeper beds; and among these, again in the same level of the lapilli bed, which had contained the skull-cap and the molar tooth, the left femur was found in August, at a distance of about 15 metres from the former; and at last, in October, a second molar, at a distance of 3 metres at the most from the place where the skull-cap was discovered, and in the direction of the place where the femur had been dug out. This tooth I did not describe, because I only found it later among a collection of teeth derived from the place stated above.

These explanations of the geological circumstances under which the four skeleton remains have been discovered, may suffice to convince anyone that they not only all come from the self-same intact, most probably young Pliocene stratum, but that they were also found in exactly the same level in this: hence they must be exactly of the same age. Their very sharp contours are opposed to the assumption that the remains originally belonged to an older bed, out of which later they have been washed. From the circumstances just stated it must, I think, clearly appear that there can be no reason to doubt their origin from rocky strata, because they were exhumed in the bank of a river, nor because they were found at some intervals of time.

It may not be superfluous to state that the femur is in entirely the same condition of fossilization as the calvaria, the molar teeth, and all the other bones found in the same stratum at Trinil. Their colour is chocolate-brown; they are harder than marble, and very heavy. The weight of the femur is not less than one kg., *i.e.* more than double the weight of a recent human femur of the same dimensions.

Sir William Turner supposed that the skull-cap showed signs of rubbing or injury, the cause of which should be that, contrary to the femur, it had been brought down with alluvia by the current of a tropical river. But the irregularities on the surface of the skull-cap, which the author of a criticism in "Natural Science" ascribes to disease, were brought about in the place of deposit only, as is proved by the fact that many other bones dug up in the neighbourhood of the cranium show the same signs, caused by the acidulous water at that place impregnating the rocks. All bones had been corroded more or less by it here.

A doubt whether the four remains were once organically connected is certainly comprehensible, and was pronounced from different sides. Nevertheless, it seems to me that this doubt is hardly allowable, on account of the short distance of the places of discovery from one another, for a distance of 15 metres is so small that as an argument against the supposition that the bones belonged to the same skeleton, it cannot be considered as of more importance than if the bones had been found in contact with one another. I often found bones from the self-same skeleton, and even fragments of one bone at corresponding distances. I dare say that every palæontologist who has made any excavations for fossil vertebrate remains has had the same experience. I never found in one place anything like a complete skeleton, and, as certainly the bones once belonged all to complete skeletons, the bones must have been all dispersed. I have good reason to think that the animals perished in volcanic catastrophies, and that their corpses were brought down in the current of a large Pliocene river. Before, then, the bones were definitely deposited and buried in the old alluvia, they must generally have been separated through the rotting of the flesh, and torn the one from the other, and dragged away with the adhering flesh by crocodiles. Many remains of these preying water-reptiles, and also the traces of their teeth in spongy parts of bones, were found. So this argument against the assumption that the femur ascribed by me to the Pithecanthropus belonged to the same skeleton as the skull-cap, fails.

Seemingly as a better contra-argument it has repeatedly been said that the result of their anatomical analysis is opposed to that assumption.

In refuting these objections I wish first to make a general remark. Apart from all disagreement in the interpretation of each separate piece, the savants, who have expressed their opinions on them, all agree in their being in a high degree human-like or anthropoid. The skull-cap is by some attributed to a Man, by others to an Anthropoid Ape, which, through the size of its skull, and some other characteristics, is the nearest to Man of all known, living and fossil, Anthropoids. The molar teeth are judged of in the same manner. The femur, however, is so human-like that nearly all, after reading my description and seeing the specimen itself, did not hesitate to declare it to be human.

But up to the present moment no human remains have been found in the Lower Pleistocene; the oldest only reach down to about the middle of that period. From the Tertiary, however, every certain trace of the existence of Man is still missing. Moreover it is a fact that, with the exception of some isolated teeth, only three small specimens of remains of fossil Anthropoid Apes have been found.

Considering, on the one side, this scarcity of remains of Anthropoids which all the researches in the whole world have brought to light up to the present moment, and on the other hand the complete absence of human remains from older strata than the Middle Pleistocene, it is certainly in the highest degree improbable that now, at once, should have been found the oldest human bone, which almost certainly goes back to the Tertiary period, and the largest fossil specimen yet known of an Anthropoid Ape, so paradoxically anthropoid that very experienced anatomists and zoologists have even taken it to be human. During five years' researches in an area hundreds of square miles in extent, and particularly rich in remains of one fauna, I did not find (with perhaps a single exception) anything which could in the slightest degree suggest the idea of a great Anthropoid or of a Man. And yet, at Trinil, those skeleton remains, as already stated, were lying close together in exactly the same level of the self-same strata, which are more than 350 metres thick, and include a homogeneous fauna. Let us imagine the proportion on a smaller scale: we have a layer of 1 millimetre (representing the thickness of the bones) in a strata-complex 3½ metres thick, and having an extent of *some thousand square metres*, and therein the four anthropoid remains (the like of which were never found elsewhere) at a distance of almost 15 centimetres, the one from the other. Certainly the probability that these remains, being exactly contemporary, are from the same skeleton is—unless the result of the anatomical examination should be *decidedly* contradictory—many thousand times greater than the reverse, viz. that the bones were never parts of the same animal.

Now, however, the *total* result of anatomical considerations which have been taken by zoologists and anatomists respecting these remains is in no way in *decisive* contradiction to their belonging together. Some, as Professor Cunningham,*

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* D. J. Cunningham, "Proceed. Anatom. Soc. of Great Britain and Ireland," February 13th, 1895, p. xviii, "Journal of Anatomy and Physiology," vol. xxix., and "Nature," February 28th, 1895, vol. li., p. 429.

Sir William Turner,* A. Keith,† also a reviewer in "Nature,"‡ and further Paul Matschie,§ Rudolf Martin,|| and A. Pettit,¶ consider both the femur and the calvaria for anatomical reasons as human remains. Professor Cunningham and Sir William Turner only doubt their individual connection, but only because they misunderstood my too short statements of the circumstances of their discovery.

Others, indeed, deny all organic connection of the fossil skull and femur. They declared the skull simian, the femur human.

Till very recently nobody followed me in absolutely regarding the remains as evidence of a transitional form between Man and Apes. Only Professor Manouvrier** in Paris, and Professor Marsh†† in America, admitted the *possibility* of it.

Regarding the femur, almost all who have made any observations on it, from my description or from personal inspection, agree on this point that they take it for the thigh-bone of a Man. With this, indeed, the fossil bone accords so well respecting its dimensions as well as considering the mechanical relations and the contours, as I myself already emphatically stated, that this interpretation seems to be the right one. Nobody, further, had the slightest doubt that the femur must have belonged to a form with an erect posture. Virchow‡‡ alone repeatedly maintained—even after having personally examined the bone—the possibility that it might have belonged to an Ape, especially to a Hylobates, because it has, in his opinion, a straight candle-like shaft, such as never occurs in Man, but is characteristic of the femur in the genus Hylobates. One can easily see, however, that the shaft of the fossil bone is by no means straight. It may be that the bending forward is not so strong as on the average in Man; in many human thigh-bones we can find it in a corresponding degree. Neither can I follow Virchow in his opinion that the fossil femur shows no essential differences with that of a Hylobates. We have only to compare their condyles with one another and with those of Man and the larger Anthropoid Apes, to be convinced that, indeed, a great difference exists.

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* Sir W. Turner, "Journal of Anatomy and Physiology," vol. xxix., p. 444.

† A. Keith, "Science Progress," July, 1895, vol. iii., No. 17, pp. 348–369.

‡ "Nature," January 24th, 1895, vol. li., p. 291.

§ P. Matschie, "Naturwissenschaftl. Wochenschrift," 1895, Bd. x., pp. 81, 82.

|| R. Martin, "Globus," 1895, Bd. lxvii., pp. 213–217.

¶ A. Pettit, "L'Anthropologie," 1895, tome vi., pp. 65–69.

** L. Manouvrier, "Bulletins de la Société d'Anthropologie de Paris," Discussion du 3 Janv. 1895, pp. 12–47.

†† O. C. Marsh, "American Journal of Science," vol. xlix., Feb., 1895, pp. 144–147.

‡‡ R. Virchow, "Verhandlungen der Berliner Anthropologischen Gesellschaft," 19. Januar 1895. Jahrg. xxvii., pp. 86, 87; and "Die Nation," 26. October 1895, p. 54.

The shape of the condyles in Pithecanthropus is quite human; in Hylobates it is entirely simian.

I described, however, features which, in my opinion, are not found in such a degree nor together in Man; the shaft is on the inner side far more round; the popliteal space is less developed, convex in its middle, so that at this height the shaft is almost round instead of flattened; the trochanteric line is less raised, and simian in its character. A fourth difference from the human femur, the shortness of the spiral line may be in connection with the exostosis which exists on the bone in this very area. Now, after having compared them with a very great number of human femora of different races, and knowing the opinion of many very experienced anatomists and zoologists, I still consider the three named characters, together, as marks of differentiation from the human femur. Similar characters, however, occur as a rule in Hylobates.

Many have thought that they could easily find these differentiating characters in human femora. But they judged especially after my description, which was rather too short; they could therefore not know the *degree* of the differences, or they did not compare the fossil femur directly with human thigh-bones. At the Leiden Zoological Congress, Dr. Rosenberg, Professor of Anatomy in the University of Utrecht, said he had found the characters in question as occasional varieties in the femur of Man; but he compared the human bones with my short description, and only saw the fossil bone a good deal later. The same human femora of the Utrecht Anatomical Institute I compared directly with the fossil bone, and I did *not* find the characters in a corresponding degree on one of them. *One* of the differentiating characters I could never find in human femora even separately. I mean the small development of the popliteal space, which is in a high degree convex, because in the midst of it, and separated from the lips of the *linea aspera*, extends a kind of swelling until near the lower extremity, which is the reason that the lower part of the shaft of the femur has such a round section. Again in human thigh-bones the most backward projecting part of that space is in the neighbourhood of the outer lip of the *linea aspera*, whilst in the fossil Java femur this lip is situated much beneath (in a forward plane) from the most prominent part, this being in the middle.* I quite agree with all who have

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* Dr. Hepburn, of Edinburgh, has pointed out to me that in Hylobates the *vastus internus* muscle, and the *femoral head* of the *biceps flexor cruris* come into close proximity to each other on the lower part of the posterior surface of the femur, *below* the level of the insertion of the *adductor magnus* muscle. They are only separated from each other by a strong *intermuscular septum*, which extends to within an inch of the knee-joint. By this means the superior part of the popliteal surface of the femur is rendered *convex*, and presents a median longitudinal elevation. An extension of these conditions of muscular attachment would exactly produce the appearances found in *Pithecanthropus erectus*.

declared the femur to be human-like in its form. It is *human-like* in all its essential features. Had I found the femur alone, I think I should have been misled to declare it to be the femur *of a Man*—by far the oldest Man—almost certainly the first Tertiary Man. I believe I should have remarked then also the less important features in which, even making a very large allowance for the variability which this bone shows in Man, it differs from a human femur. But these slight differences I should perhaps have regarded as evidence of another species only. But now, considering its, in my opinion, unmistakable connection with the very ape-like cranium and these simian teeth, without forgetting that the femur is *human-like* in all its essential features, I *cannot* regard it as the femur *of a Man.* And considering the finding of it in close proximity to the ape-like skull and teeth, I see in the features by which this femur is different from all existing races of *Man*—though they may be mechanically unimportant—*more* than a special difference.

I have to account, then, for the heterogeneous combination of these parts in one body which, according to our knowledge of living species, seems to be paradoxical.

Professor Manouvrier, the well-known Paris anthropologist, to whom I showed the Javanese femur, declared he had never seen, as far as he could remember, a similar feature of the popliteal space in human thigh-bones, of which he has examined many hundreds.* I acknowledge that the *possibility* still exists that the bone, nevertheless, may be a human femur. But considering the circumstances under which the femur was found, namely, in exactly the same horizon of one stratum and in the closest proximity to the skull-cap and the teeth, which circumstance prove their exact synchronism, it seems to me to be far more natural to doubt the human nature of the femur in case the other remains should be proved, on account of the anatomical examination, to be not human. Manouvrier and Dr. Arthur Keith† point out that the human form of the Trinil femur is not sufficient to prove that it did not belong to the same individual as the skull-cap; for, the phylogenetic evolution of the human femur ought to have preceded that of the skull, as the erect attitude and the erect locomotion have been the cause of the intellectual perfection. Suppose a species of Anthropoid Ape—whose frame rather resembles the human—suppose a large Hylobates, should strive to perfect the pedal locomotion, which this genus already has when walking on the ground—it would, on account of the close relation existing between form and function of the femur, be hardly imaginable

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* Later on he wrote to me, that he at last had found some specimens showing similar, though not exactly the same, features. These cases may be regarded as atavistic varieties.

† L. Manouvrier, *l. c.*; A. Keith, *l. c.*

that this bone could be different from that of man in important characters. In the opinion of Manouvrier, Keith, and myself, there might, therefore, exist a form, the skull of which had still many simian peculiarities, whilst the femur was to be distinguished from the human bone in quite subordinate and mechanically unimportant characters only.

Such an Anthropoid would have the same proportion between the length of the femur and the size of the skull as the Pithecanthropus; for we have only to double the length and breadth, both of the thigh-bone and of the skull of a *Hylobates syndactylus*, to have dimensions exactly corresponding to those of the Java form. By doubling all dimensions of a Hylobates we would obtain an *imaginary* product with a corresponding cranial capacity also. But certainly such an enlargement alone would not be adequate to explain *in reality* the large cranial capacity, as, with an enlargement of the size of the body in nearly allied species of mammals, we do not find a corresponding enlargement of the cranial capacity. The Anthropoid would therefore not only have grown in the size of the body, but his brain would have grown *faster* relatively to the body than we are accustomed to see in homogeneal mammal species of different size. This is actually what we find to be the case in the remains of Pithecanthropus, and is indeed a proof that this fossil form was on the direct road to human development, the special morphological character of the genus *Homo* being the large cranial capacity of the skeleton relatively to the size of the body.

For normal human proportions, the capacity of the cranium is too small for the femur, but microcephalic skulls of the class which may be regarded as atavistic can be even relatively smaller, whilst the height of the body is more than that of the Pithecanthropus, as computed from the length of the femur. Such was the case with the microcephalic idiot Joe, described by Professor Cunningham; this was at least 5 cm. taller, but the capacity of his cranium measured only 620 c.cm. Comparing only the lineal dimensions, the length of the cranium of Pithecanthropus is certainly *not* too small for normal human proportions, assuming the femur to have belonged to the same individual—I measured many human skeletons having the same proportion — but certainly it would not be high enough.

The fossil femur has a large exostosis growing from the inner and back part of the shaft below the lesser trochanter. That this pathological formation may have greatly changed the normal general form of the femur is, in consideration of other similar femora, very improbable. Of those who more closely examined the femur after my description, or the bone itself, none have admitted that. The celebrated pathological anatomist Virchow declared at the Leiden Zoological Congress the exostosis to be the result of a healed caries, which descended from the lumbar vertebræ along the *psoas* muscle, and demonstrated a similar human femur, which, in other respects, was very normal in its form. However, the situation of the exostosis *below* the *trochanter minor*, into which the *psoas* is inserted, does not well agree with the opinion of Virchow.

The divergence of opinions regarding the interpretation of the skull-cap has been far greater than that concerning the femur. Whilst on the one side W. Krause,* at the January meeting of the Berlin Anthropological Society, stated, as his opinion, that the skull-cap belonged, without any doubt, to a large Ape, and on another occasion declared it to be that of a Hylobates; whilst Waldeyer† stated that the skull-cap might be attributed to a Hylobatide, and again (at the Anthropological Congress of Cassel), that it could only have belonged to a higher form of Anthropoid Ape; Professor Cunningham,‡ at a meeting of the Royal Dublin Society, regarded the cranium as undoubtedly human; and also Sir W. Turner§ and A. Keith‖ considered it as a human remnant. Rudolf Martin¶ is of the same opinion, and finds a total conformity in all real points with the human skulls of Neanderthal and Spy. The reviewer in "Nature"** considers it as that of a microcephalic idiot. And more recently Topinard†† declares the skull-cap to be human and Neanderthaloid. He considers "la question jugée," whilst, nearly at the same moment as his article appeared, three other famous Paris anthropologists, MM. Hamy, Manouvrier, and Verneau, declared, after having examined the skull itself, that it could not be human. At the Leiden Zoological Congress, Virchow declared the Java skull to be an Ape skull. In the opinion of Sir William Flower and Professor Marsh, who were present at the same session, it cannot be human, nor can it be regarded as that of a true Ape.

Any one can see at a glance that this Java cranium is very large in comparison with the skulls of Anthropoid Apes. Its length is 185 mm., its breadth 130 mm. The same dimensions in a female chimpanzee skull, an average one, are 132 and 91, those of the skull of a *Hylobates syndactylus* 95 and 69. The three form exactly a geometrical series. The internal capacity of the cranium I estimated from a comparison of the length, breadth, and arch of the vertex of the skulls of the Chimpanzee and Hylobates, with the same linear dimensions of the fossil, and from the actual capacities of those Ape skulls, to have been about 1000 c.cm. Manouvrier, estimating the capacity through the method of the cubic index, came to the same conclusion as I did. According to this we may take a skull capacity of about 1000 c.cm. as approaching very near the reality.

What therefore is most striking in these measurements, as already from the

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* W. Krause, "Verhandlungen der Berliner Anthropol. Gesellschaft," 19. Januar 1895, xxvii., pp. 79 and 80.

† Waldeyer, *ibid.*, p. 88. ‡ "Nature," *l. c.* § *l. c.* ‖ *l. c.* ¶ *l. c.* ** *l. c.*

†† "L'Anthropologie, Septembre–Octobre, 1895," tome vi., No. 5, p. 605.

direct inspection of the skull, is its excessive size in comparison with that of the skulls of all the Anthropoid Apes, the smallness of the braincase in comparison with that of a Man. The largest skulls of Anthropoid Apes have no larger mean capacity than about 500 c.cm.; and only very seldom skulls have been measured of Gorilla, the capacity of which attained 600 c.cm. The difference then in the size of this fossil skull-cap with that of Anthropoid Apes is very important.

In normal human skulls, however, the length and breadth and the capacity have been found exactly corresponding with, or even smaller than, in the Java cranium. Crania with a capacity of about 1000 c.cm. are not rare in Australians, Andamanese, and Weddahs. Sir William Turner found the average capacity of twelve Australian women only about 100 c.cm. higher. Three of these measured even less than 1000 c.cm. Sir William Flower measured a Weddah and an Andamanese skull (both feminine) with capacities of about 1000 c.cm. The cousins Sarasin found the average capacity of Weddah skulls little above 1100 c.cm.; the feminine minimum little above 1000 c.cm. It is known, however, that the internal capacity of the skull is doubtless dependent on the size of the body, and these small capacities seem always to be in connection with a small body. The Andamanese and Weddahs are very small. The Drs. Sarasin give as average height of the body of Weddah women only 143 cm. That of the Andamanese will, as I believe, according to the height of eighteen men I have seen of that race, surely not be greater. Granting that the femur of Trinil belongs to the skull, the height of the body of this individual must be estimated, according to human proportions, 165 to 170 cm. We find, then, the skull for a human being to have so low a capacity as cannot exist even as a physiological minimum. Assuming, then, the skull does belong to the femur, the Trinil individual, if a human being, ought to have been a microcephalic idiot, a most extraordinary case. Under many millions of men not one is born a microcephalic idiot. It would then have been a likewise extraordinary and most improbable accident if, at Trinil, I had found just such an idiot. Therefore it is far more probable, assuming the femur to belong to the skull, that we are not dealing with a human cranium.

The Trinil cranium, through its form and size, very much approaches the type of Anthropoid Apes; this everybody, who inspects the specimen, will immediately observe. The size, too small for a normal human skull, the smallness of the arch of the vertex, and the low receding forehead, the *torus occipitalis*, and especially the strong projection of the orbital parts of the frontal bone, are all simian features. Again, the superior occipital ridge seems to unite with the posterior part of the temporal ridge, and to form a marked swelling, a feature which, as a rule, is seen in all full-grown Apes, but never in human, not even in microcephalic skulls.

Professor Cunningham, Sir William Turner, and others, have compared the calvaria of Trinil with the crania of Neanderthal and Spy. Indeed the agreement with these is great, as I already stated in my first description. I then avoided closer comparison, because they had been held by Virchow and others to be pathological. But recently I have been in Liège, and there have studied, during nearly a whole morning, together with Professor Fraipont, his famous Spy-skulls, one of which is exactly like the Neanderthal skull, comparing them directly with the Java calvaria. I am now wholly convinced that they are not at all pathological, and was much struck by the great resemblance with the cranium of Pithecanthropus. Both Professor Fraipont and I could find no other decisive differentiating features except the size, the flattening of the parietal region in the Java calvaria, and the relatively much greater dimensions of its orbital part. Also the same two more important last-mentioned differences I find only between it and the very interesting atavistic microcephalic skull described by Professor Cunningham. These characters of the Java calvaria I believe it would be impossible ever to find in human crania. No microcephalic skull, so far as I know, shows them. It may be that the Trinil skull is in other respects to be compared with the Neanderthal and Spy skulls, as also with microcephalic skulls, yet it is different from these, also through its lesser size. For the Neanderthal skull, Huxley estimated the capacity at 1230 c.cm.; others, with more right in my opinion, estimated these at 300 c.cm. higher; in any case the linear dimensions of the Neanderthal skull are greater than those of the fossil skull, and the same holds for the Spy skull; their length and breadth are about 15 mm. more.

On closer comparison with a distinct genus of Anthropoid Ape we find—as I stated before, and as many naturalists, who saw the skull-cap or even my figures, grant—the next analogous is Hylobates. From this genus I really can only find two important differences, viz. in the size and in the downward slope of the occiput. The "orbital part of the skull"—as it was recently termed by Virchow—is quite different from this part in Man. I have good reason to suppose that not unimportant pieces of this part have been lost; but still it is not difficult to see, on the right side of the fossil calvaria, that it is not at all like that in Man. The proportion between the lengths of the orbital and cerebral parts of the skull-cap is exactly the same as in the skulls of the Gibbons. I therein quite agree with Virchow. Only the dimensions of the fossil skull are about twice as large as those of the largest Gibbon skull. In Hylobates only do we find sometimes the supra-inial arch of the cranium as high as in the Pithecanthropus.

I will now go a little closer into a very important character, by which the Java cranium, notwithstanding its resemblance to the Ape, especially Hylobates, is more decidedly related to human structure. I mean the strong slope forward of the infra-inial part of the occiput. It was, without doubt—as Sir William Turner, when speaking of my description, also admits—in relation with the curve of the encephalon, and the greater relative volume of the cerebrum, which are associated with the erect attitude. It is much stronger than in the Anthropoid Apes, and differs only a little from human proportions.

In fig. 2 I have drawn the *opisthion* (*i.e.* the median point of the hinder border of the *foramen magnum*) of the fossil cranium on the ground of comparative measurements of the cranium No. 2 of Spy, and of many Hylobates' skulls, which also in the form of the related region approach nearest the Trinil cranium. The curves are then placed on one line, in equal length for all drawn from the opisthion to the *glabella.* The inclination of the nuchal part of the occiput is much nearer to modern Man than to the Anthropoids ; for other human skulls, which I measured for this purpose, are in proportion almost exactly the same as the Papua skull, which is drawn here. The Spy cranium and that of the microcephal Joe, described by Professor Cunningham, approach very much that of the Pithecanthropus.

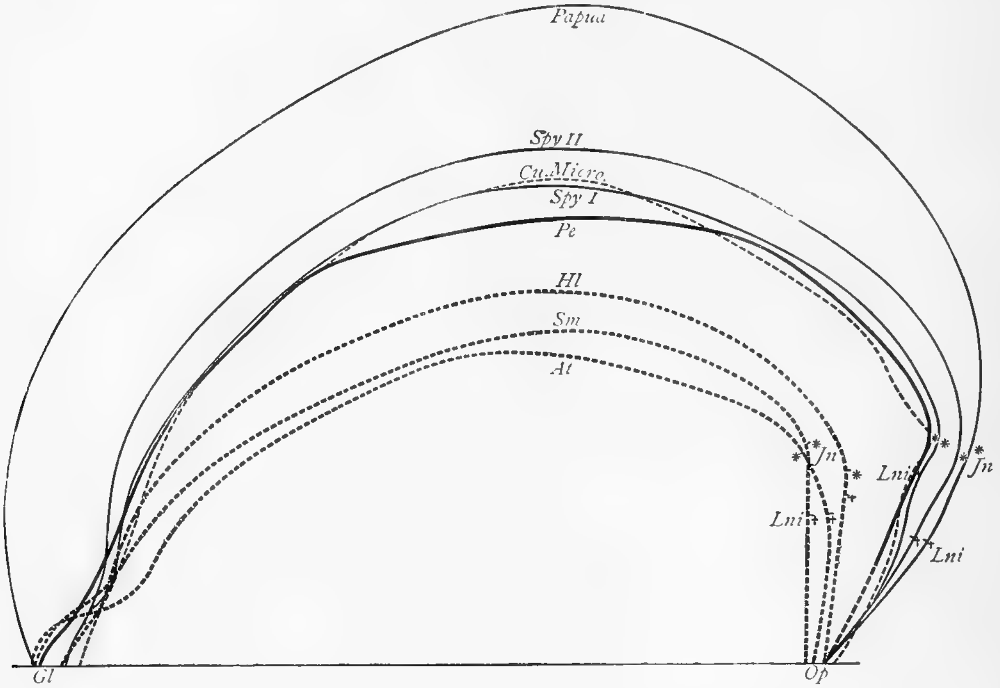

FIG. 2.—Profile outlines of the skulls of *Pithecanthropus erectus* (Pe), a Papua man, the Spy man No. 1, the microcephal Joe described by Professor Cunningham, and of *Hylobates leuciscus* (Hl), *Semnopithecus maurus* (Sm), and *Anthropopithecus troglodytes* (At). Gl—Glabella. Op—Opisthion. Jn—Linea nuchæ superior. Lni—Linea nuchæ inferior.

In the Chimpanzee, the Gorilla, the Orang-utan, and the different species of Hylobates, I find that the angle which the median line of the nuchal plane makes with the median line from the glabella to the hinder bord of the *foramen magnum* only varies between 94° and 97°. In the lower Apes I find it in *Semnopithecus* *maurus* equal to 90°; in *Macacus cynomolgus* to 84°. In the cranium of Pithecanthropus, however, it is equal to 115°, which is much nearer to Man; for in recent human skulls it is generally about 130°; in the microcephal Joe, described by Professor Cunningham, 112°; in the skull No. 2 of Spy, 124°.

Certainly the position of the superior nuchal line is somewhat variable in every species, this point shifting up and down according to the development of the nuchal muscles; but then the *inclination of the nuchal plane* to the glabellar-opisthion line may still be nearly constant in each species, as it seems to me to be according to the human and Ape skulls I have just mentioned, nor could the degree of this inclination in Pithecanthropus be much influenced by the varying position of the superior nuchal line.

It might be possible that among an immense number of Anthropoid crania one is to be found which more approached the human proportions than the six crania of Anthropoid Apes stated, belonging to four genera and six species. This cranium of Pithecanthropus might also be an exceptional case in its kind and very different from the average. But, on the one hand, among a large number of Anthropoid crania, and a still greater number of human skulls, I did not find, even in a single case, a considerable deviation from the average; on the other hand, the probability that the fossil cranium found should be an exceptional case is very small.

As Professor Rosenberg, of Utrecht, in the discussion upon these fossils, which took place during the Leiden Zoological Congress, rightly remarked, the American Monkeys are even nearer to Man by the strong forward slope of the nuchal part of the occiput, than the Anthropoid Apes, and they do not walk more upright. As it appears to me the New World Apes, however, stand too far off from Man to allow of a more direct comparison, and to regard this feature as a real homologue of that in Man. For the same reason nobody would be likely to bring the analogous high-arched forehead of those Apes in closer comparison with the human frontal arch.

Almost the same divergence relative to the skull exists in the interpretation of the molar tooth which I described. W. Krause* said of it that there is no doubt that it is the molar tooth of an Ape. Ten Kate† had the same opinion. Rudolph Martin,‡ on the contrary, said it is totally human-like, and only different from the human tooth by a greater breadth of the crown. The reviewer in "Nature"§ also thinks the tooth may be human. According to Arthur Keith,‖ however, it closely resembles the very variable third molar of the Orang. He thinks the crenation of the posterior fringe of the tooth is practically diagnostic of its being an Orang's tooth. On a later occasion, however, Keith regards the tooth as human.¶ Professor Cunningham** said that the fossil tooth is fashioned more after the

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* *l. c.* † "Nederlandsch Koloniaal Centraalblad, Leiden, 1895," p. 128. ‡ "Globus," *l. c.*

§ "Nature," *l. c.* ‖ "Proceed. Anat. Soc.," *l. c.* ¶ "Science Progress," July, 1895, vol. iii., p. 350.

** "Nature," *l. c.*

human model than the simian. Sir William Turner,* on the contrary, inclines to ascribing the tooth to an Orang-utan, and doubts, on account of its large size, that it could have belonged to a man. In Manouvrier's estimation the tooth is, through its dimensions, simian; through the crown surface, however, more human.†

In close proximity to the place where the skull and the tooth already described were found, and in exactly the same level again, a second molar of the left side was dug out a year later, but in the same year as the femur. The crown of this is in its transverse dimensions a little smaller than that of the third molar; in its sagittal dimensions, however, it is somewhat larger. The roots are a little shorter, but as strongly divergent, and in the same way directed obliquely backward. They are, in both molars, modelled after exactly the same type, so that for these reasons alone the connexion of these two would be highly probable; but also the crenation of the crown is the same as that of the third molar; the dimensions, as I said, are not very different, and it shows a similar, relatively strong retrogression of the cusps, which are of the same type. The crown of the second molar is far more worn off, and shows at its circumference in front and behind a grinding facet against the neighbouring teeth. The circumstances in which they were found, together with the result of their comparison, prove, in my opinion, that these two teeth are certainly from the same individual. The objection that they cannot belong to the same individual on account of the different degree in which their crowns are worn off, was easily set aside by comparing them with teeth in the skulls of a Gibbon and an Orang-utan, which I demonstrated at the Leiden Congress, as also several human skulls. In these the third molar had only been a short time in function, just as the wisdom-tooth of the Pithecanthropus, whilst the other two molars already showed a strong wearing off.

Thus the objection that the third molar could not belong to the skull-cap, because it is certainly from an old individual, is at the same time set aside. The crown of the wisdom-tooth being larger than that of the second molar is often to be seen in Man. Some pregnant cases I have measured in the rich craniological collection of the Anatomical Museum in Leiden.

This second molar tooth shows a similar retrogression of the crown as the third. Nevertheless, like the third molar, it is of the simian type. In Man, of the four cusps on the crown of the upper molars, the smallest is the *lingual* posterior cusp. On the contrary, as in the Anthropoids, one of the cusps becomes smaller; it is always the *buccal* posterior cusp.‡ Now, of the crown of the second molar tooth from Trinil, the *buccal* posterior cusp is in retrogression exactly, but in a slighter degree, as in the third molar. The examination of this tooth,

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* "*l. c.* p. 443. † *l. c.* p. 17.

‡ Very rarely the reverse is the case, and only with the third upper molar.

therefore, justifies the conclusion drawn from the third molar that the teeth of the relative individual were still of the Ape type.

As to the dimension of the crown, the two teeth are neither too small nor too large, in proportion to the size of the skull, to admit of these remains belonging to a large Anthropoid Ape. In female Hylobates I find the proportion between the breadth of the skull and the transverse diameter of the second upper molar (which is always less variable than the third) exactly equal to that in Pithecanthropus; in male Hylobates, and even in the females of the Chimpanzee, the second upper molar is relatively somewhat larger. For human proportions, however, the dimensions are rather large. I only found in one of the maxillar bones of Spy a second molar having exactly corresponding dimensions of the crown. But such large and strongly divergent fangs of the roots, I believe, are never to be found in human molars.

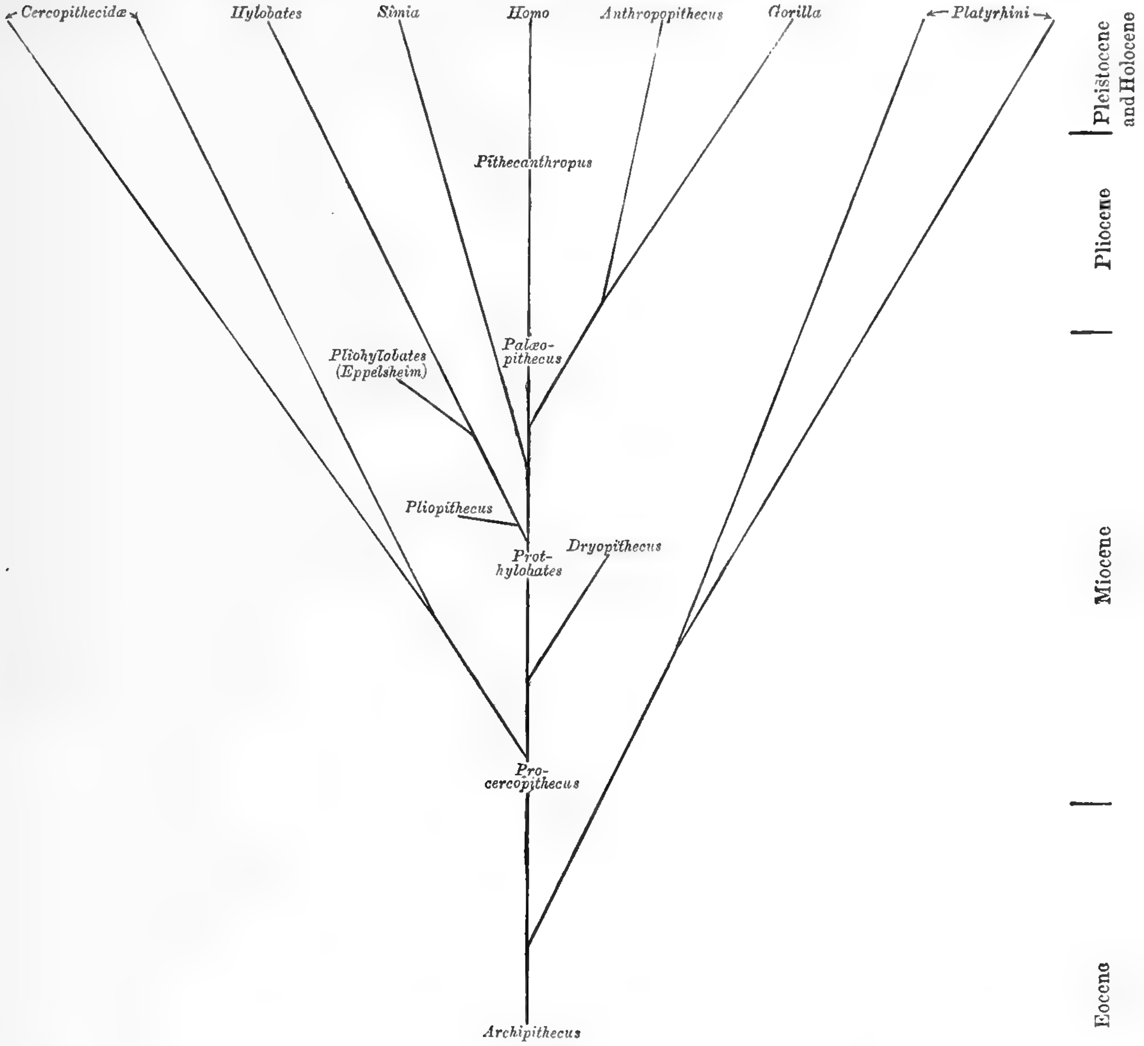

FIG. 3.—Genealogical tree of Man and the Apes.

From all these geological and anatomical considerations, it follows that, in each of the four specimens, we may have before us evidence of a form intermediate between Man and Anthropoid Apes; that, moreover, the anatomical examination of the specimens, as well as the circumstances of their discovery, make it exceedingly probable that they belonged to the same individual. I therefore believe that I may maintain my conviction that these four remains belonged to a transitional form between Man and Apes; and further, that this form not only represents a peculiar genus, but is also as different from all Anthropoid genera as from Man; that the founding of a new family between the Hominidæ and the Simiidæ was necessary for it—if we do not prefer to revert entirely towards the Linnæan classification, and separate Man only generically from the Apes, nor much enlarge our definition of one or the other of the families named. And so far as I can see, there is nothing against regarding this form as being in the direct genealogy of Man.

The problem now before us is the exact position of this intermediate form in the genealogy. In my opinion it belongs to the direct line, but before it had become human.

I have attempted to give in fig. 3 a diagrammatic representation of my views with reference to the phylogenetic evolution of Man and the Apes.

In the Eocene we have Haeckel's hypothetical genus Archipithecus, from which arose first the branch of the Platyrhine Apes. In the early Miocene, from a common hypothetical Procercopithecus, the ancestor of the Old World Apes, there originated the branch of all the Lower Old World Apes, the Cercopithecidæ. Afterwards, in the Middle Miocene, when the main line had become more Anthropoid, there branched off Dryopithecus, which, according to later researches of Gaudry, is intermediate in its characters between the lower Catarrhine Apes and the Man-like Apes. Still higher up in the Miocene originated the hypothetical form Prothylobates, a very generalised form, which I regard as the ancestor of all the Anthropoid Apes and Man. During the Middle and Upper Miocene, there developed from this stem-form, first a branch giving rise to Pliopithecus, and the form from which we have the femur of Eppelsheim ("Dryopithecus" of Pohlig), which I call Pliohylobates, and ending in the existing genus Hylobates; secondly, branches giving rise to Simia, and to Troglodytes and Gorilla. Lastly, we have in the direct line, originating from Prothylobates, during the Lower Pliocene or Upper Miocene, the Siwalik Palæopithecus, which, after a careful examination in the Indian museum at Calcutta of the specimen on which the genus is founded, I regard as a decidedly Hylobatoid form, but approaching towards Man. Between this form and Man comes in the Upper Pliocene, Pithecanthropus, which, while still retaining many Hylobatoid characters, approaches, as I have tried to show, nearest of all to Man, but cannot be placed in the genus *Homo*.

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II.

ON THE DEVELOPMENT OF THE BRANCHES OF THE FIFTH CRANIAL NERVE IN MAN.

By A. FRANCIS DIXON, B.A., M.B., Chief Demonstrator of Anatomy, Trinity College, Dublin.

(Plates I. and II.)

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[COMMUNICATED BY PROFESSOR D. J. CUNNINGHAM, M.D., F.R.S., HON. SEC., R.D.S.]

[Read December 18, 1895.]

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General Statement.

The following observations on the development of the branches of the fifth cranial nerve in man were undertaken at the suggestion of Professor His, who was not only kind enough to give me a place in his laboratory, and permission to make models of the cranial nerves in his beautiful series of human embryos, but has also given me much valuable assistance in carrying out the work itself.

Up to the present, if we omit the short description given by Professor His,*

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* "Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim menschlichen Embryo." Abhandlungen der Königl. Sächs. Ges. d. Wissenschaften, 1888. Bd. xiv. p. 341.

no detailed account of the development of the branches of the fifth nerve in man has been published.

In animals lower in the scale, however, a large number of observers have given accounts of the condition of the fifth nerve in the earlier stages of development, and also in the adult forms. Among these may be mentioned Ahlborn, Scott, Shipley, and Kupffer in Marsipobranchii; Marshall and Spencer, Béard, Ewart, Miss Platt, Dohrn, and many others in Elasmobranchii; Strong, Wiedersheim, and Plessen and Rabinovicz in Amphibia; Hoffmann and Béraneck in Reptiles; His, Marshall, Béraneck, and Goronowitsch in Birds; and recently Chiarugi in the Guinea-pig.

From the observations of these authors it is certain that in Marsipobranchii, Elasmobranchii, and Reptilia, at all events, the fifth nerve in the earlier stages, and even in the adult of some forms, possesses two distinct ganglia.* From the anterior of these two ganglia the ophthalmic division of the fifth, or a part of it, takes origin; from the posterior ganglion arise the superior and inferior maxillary divisions. In birds and reptiles the superior maxillary nerve is a later formation than the inferior maxillary, and is developed as a branch of this latter. In man and other mammals, on the other hand, a special ganglion for the ophthalmic nerve, in the sense of a ganglion on a posterior nerve-root, is not present, although attempts have been made to prove its existence. Further, in man the three main divisions of the fifth appear to rise independently from the Gasserian ganglion.†

The description given by Professor His of the fifth nerve, in the paper above referred to, deals with the origin and early stages in the development of the three great divisions of the nerve, as well as with the development of the fifth nerve roots. In the present investigations, on the other hand, following Professor His's suggestion, an attempt is made to trace the development of the different branches of the fifth, starting with an embryo of four weeks, at which time the three main trunks are alone represented. Further, special attention has been paid to the development of those nerves, which in the adult connect the fifth with other cranial nerves, as the often assumed transmission of taste impulses by these connecting nerves adds great interest to their mode of origin and earliest attachments. The connections of the accessory ganglia of the fifth nerve, and as far as possible the date of their appearance in the embryo,

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* Béraneck also describes two ganglia as present in connection with the Trigeminal in the early embryo. "Etude sur les Replis médullaires du Poulet." Recueil Zoologique Suisse, 1888, vol. iv. p. 337.

† This does not seem to be the case in the Guinea-pig; further, in this animal, at the time of origin of the fibrous ophthalmic nerve, a small ganglion is present, which later fuses with the Gasserian. Chiarugi. "Lo sviluppo dei nervi oculomotore e trigemello," nota preliminare. Monitore Zool. Ital. v. 1894), p. 275.

have been noted. The mode of origin of these ganglia in mammals must still be looked upon as an unanswered question; but at all events it may be asserted that they resemble spinal ganglia neither in their mode of origin, nor, as Retzius has shown, in their microscopic structure.

In this Paper the branches of the fifth nerve are described as growing out from the Gasserian ganglion in the manner described by Professor His, and the fibres which compose them are referred to as processes of the cells in this ganglion.

Goronowitsch* has recently shown in the chick embryo, that before the axis-cylinder processes are formed, and therefore before true nerves are present, cords of cells derived from the mesenchyme occupy the positions of the future nerves. These tracts of mesenchyme he called "Nervenführendes Gewebe," and he considers that later on they form the different parts of the nerve sheaths, the axis-cylinders alone arising from the ganglionic cells. Dohrn† on the other hand, from observations on Elasmobranch embryos, considers, that the axis-cylinders are not processes of the ganglionic cells, as they are usually believed to be, and that the nerves arise by cells, uniting together in a chain-like manner.

More recently still, Sedgwick‡ in his attack on the cellular theory of development, from observations also on Elasmobranchs, states that nerves are formed by the fibres of the mesoderm reticulum falling into line. These fibres, according to Sedgwick, first become re-arranged to form nerves in the region of the ganglia, and so it thus comes about that the nerves appear to grow out from the latter, but the axis-cylinders are not processes of ganglionic cells. All observers agree that the nerves, no matter how formed, appear to grow out from the ganglia.

It would appear to be an assured fact that in lower animals before the axis-cylinders are formed, cellular tracts—"nerves"—are present. These have been noticed by many authors in different animals, and Kupffer§ has described and figured such for the fifth nerve in Petromyzon. Kupffer regards them as outgrowths from the ganglia, while Goronowitch apparently considers similar structures in the chick to be chiefly mesodermic in origin. Speaking more recently of these chains of cells in the case of the spinal nerves Kupffer

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* Untersuchungen über die Entwicklung der sog. "Ganglienleisten" im Kopfe der Vögelembryonen. Morphologisches Jahrbuch, 1893. Bd. 20. p. 187.

† "Nervenfaser und Ganglienzellen. Histogienetische Untersuchungen." Mittheilungen aus der Zoologischen Station zu Neapel. Bd. 10, p. 255.

‡ "On the Inadequacy of the Cellular Theory of Development, and on the Early Development of Nerves, particularly of the Third Nerve, and of the Sympathetic in Elasmobranchii." Quarterly Journal of Microscopical Science, vol. 37, 1894, p. 87.

§ "Die Entwicklung von Petromyzon Planeri." Archiv für Microscopische Anatomie, 1890. Bd. 35 p. 520.

distinctly states: "die primitiven Ketten gleichsam nur die Leitbahnen abgeben, längs welcher die Fibrillen in der einen oder anderen Richtung vorwachsen."*

It is probable that such cellular tracts also occur in mammalian embryos, but here they are not at all sharply defined from the surrounding mesoderm. At all events it is certain that when a developing nerve is first recognisable nuclei are far more plentiful among its fibres than they are after the nerve is well established.

The observations recorded in this Paper were commenced at Leipzig in the summer of 1893; and, since then, I have attempted to verify the results obtained for the human embryo by the study of a number of rat embryos of different ages by means of models constructed from microscopic sections. In every important particular a complete correspondence was found to exist between the human and the rat embryos. The nerves appear in the same order, and the connections of the fifth with the other cranial nerves are developed in the same manner.

The five stages in human embryo described in this memoir are Professor His's embryos:—

Br.$_3$,	four weeks old,	6·9 mm.
Ru.,	fifth week,	9·1 mm.†
C. R.,	beginning of sixth week,	13·6 mm.†
F. M.,	seven weeks old,	17·5 mm.†
Mr.,	eighth week.	(See figs. 1 to 4, Plate I.)

In addition to these five stages, models were also made of the cranial nerves in embryos Wt. and Ob.; but, as one of these is only a little older and the other a little younger than F. M., separate detailed accounts of them are not given.

Method of Investigation.

I had not proceeded far with this work before it became evident that the more usual method of microscopic reconstruction by the use of wax plates would not yield satisfactory results in modelling fine branching nerves. This difficulty was overcome by Professor His, who suggested to me that the reconstruction might be effected by means of glass plates. The process is a very simple one. A series of sections through the head of an embryo, having been drawn enlarged 25 or 50 diameters, by means of a camera lucida, the drawings are traced on to glass plates covered by a transparent varnish, such as is commonly used in coating photographic negatives. These glass plates are 25 or 50 times as thick as the sections, and it therefore follows that when they are placed one over another, a model of the head of the embryo, with its nerves, vessels, brain, &c., 25 or 50 times

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* "Studien zur vergleichenden Entwicklungsgeschichte des Kopfes der Kranioten," München, 1894. Heft ii., p. 75.

† Measured from cervical to caudal bend.

enlarged, results. Sometimes it is only necessary to draw every second section, and in these cases glass plates twice as thick were employed. In places where nerves cross, or where they are closely applied one to another, it is necessary to draw every section. By the use of different coloured inks for the different nerves and vessels, the tracing of the relative positions and connections of the various structures in the model is simplified. It is advisable to gum small pieces of paper on the glass plates near the corners, so as to prevent the varnish being rubbed, or scratched; where this occurs the model becomes opaque. Further, in drawing the outline of the larger structures, such as the brain, experience showed that it was well to use only dotted lines. When thick lines are multiplied in the model, the whole becomes too dark, and the nerves are not easily seen or traced as they pass behind these more solid structures. Models constructed in this way have the great advantage that they can be cut in section at any point by simply separating the plates, or indeed, if desired, any individual section can be studied. Further, if a mistake is found at any place, the faulty plate or plates can be removed, washed under running water, and re-drawn.*

When the model consists of a very large number of plates, 100–200, it cannot be viewed as a whole even by a bright transmitted light; but it is very useful to divide it up into a number of parts of from 10–20 plates, each of which we may take to represent a very thick section through the head multiplied 25 or 50 diameters. The drawings accompanying this paper are made from such groups of plates, and the actual thickness of the sections which they represent are given in each case.

Ophthalmic Division of the Fifth Cranial Nerve.

EMBRYO BR$_3$.—(4 weeks, 6·9 mm.). Figure 5, Plate I.

In this embryo the ophthalmic nerve is represented by a relatively thick trunk, taking origin from the highest point of the Gasserian ganglion.

This trunk is short, being only 0·4 mm. in length, and its direction is almost directly upwards behind the eyeball. Towards its termination, however, the nerve turns slightly inwards, the turning inwards corresponding to the narrowing of the head at this level. The nerve-trunk gives off no branches. Among the fibres of the nerve a number of nuclei are present, but no aggregation of these into an isolated ganglion was found. These nuclei are most plentiful near the origin of the nerve from the Gasserian ganglion.

As a rule it was noted both in man and in the rat that nuclei are most plentiful among the fibres of a nerve near its origin from the ganglion from which it grows out, and further, they are more numerous in the early than in the later stages.

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* Dr. Oskar Israel in his Practicum of Pathological Histology, Berlin, 1893, p. 96, attributes to Klebs a method of reconstruction similar to the one here described. I have not been able to see Klebs's original description.

The third nerve, passing from above and behind, downwards, forwards, and a little outwards, ends close to the inner side of the origin of the ophthalmic nerve.

EMBRYO RU.—(5th week, 9·1 mm.). Figure 6, Plate I.

In this embryo the ophthalmic trunk, rising from the upper and anterior part of the Gasserian ganglion, passes upwards and slightly inwards, and soon divides into anterior and posterior branches.

Among the fibres of the nerve, near its origin, a number of nuclei are present, which are seen to be more numerous in the section of the posterior part of the trunk. Of the two branches into which the ophthalmic nerve divides the posterior, although the shorter, is more the direct continuation of the main trunk, as far as direction goes, than the anterior branch. Further, as seen in section, the two branches differ from one another; thus, the fibres of the posterior branch are not so distinct, and, throughout its whole length, it stains more deeply than the anterior branch, and nuclei are present in greater numbers among its fibres. These points of difference can be made out in the nerves of both sides.

The common trunk of the ophthalmic, before its division into anterior and posterior branches, is only about 0·08 mm. long.

The posterior branch of the ophthalmic passes upwards, inwards, and slightly backwards, behind the eye-ball; its length is 0·16 mm.

The anterior and longer of the two branches of the ophthalmic is directed forwards, and a little upwards, across the optic stalk; near its termination, however, it turns a little outwards. The anterior, or distal extremity of this nerve, reaches farther forwards than the front part of the eyeball, and lies only 0·2 mm. from the inferior surface of the front part of the brain. The place where this nerve crosses the optic stalk is just at the point where the latter joins the eyeball. The length of this nerve is 0·84 mm. From a comparison of these two branches with those of later embryos it is found that the anterior branch represents the nasal, and the posterior the frontal nerve of the adult.

In this embryo, also, no defined collection of nuclei was found in connection with the fifth nerve, which might be considered to represent a ciliary ganglion.

The third nerve, coming from above and behind, passes downwards, forwards and outwards, some distance to the inner side of the posterior (frontal) branch of the ophthalmic. Having passed along the inner side of the Gasserian ganglion, it ends below the optic stalk, at the level of the origin of the superior maxillary nerve. The third nerve gives off no branch, and from its course it is evident that it is the inferior division of the third nerve of the adult that is represented in this embryo. No aggregation of cells into a distinct ganglion was found connected with the third nerve.

The fourth nerve ends 0·6 mm. from the termination of the frontal.

The sixth nerve runs upwards and outwards, and ends near the termination of the third nerve.

Ru.—Ophthalmic nerve = 0·08
Frontal branch = 0·16
Nasal branch = 0·84

Embryo C.R.—(beginning of 6th week, 13·6 mm.). Figures 7 and 8, Plate I.

The ophthalmic nerve arises from the upper and anterior part of the Gasserian ganglion. The main trunk is short (0·24 mm.), and divides into two well marked branches. Both of these branches pass upwards and forwards, one lying behind the other. The more anterior branch, which represents the nasal of the adult, crosses the optic stalk, just where the latter joins the eyeball. The posterior or frontal branch also crosses the optic stalk, but is placed farther above it. From the posterior branch, just at its origin, a fine nerve passes outwards, behind the eyeball. This represents the lachrymal of the adult. The length of this lachrymal nerve is about 0·6 mm.

The nasal and frontal branches, from their origin, at first pass upwards and forwards, nearly parallel to one another, the frontal being not only posterior to, but also higher than, the nasal. After a course of about 0·7 mm. they turn in different directions, the frontal passing upwards, forwards and outwards, the nasal upwards, forwards and inwards. The frontal nerve takes a more distinctly ascending course than the nasal.

The nasal nerve having given off a small branch, which seems to represent the infratrochlear nerve of the adult, turns more inwards and comes to lie to the outer side of the olfactory nerves. In this part of its course the nasal nerve lies between the under surface of the anterior part of the brain above, and the upper part of the nasal pit below. Before its termination the nasal nerve turns slightly downwards and forwards. The entire length of nasal nerve is 1·5 mm.

The infratrochlear branch passes forwards from the point where the nasal nerve turns inwards: it is not more than 0·2 mm. in length.

The frontal nerve is larger than the nasal, and lies above and behind it at first; ceasing to run parallel to the nasal nerve, the frontal turns outwards and divides into two branches—supratrochlear and supraorbital. The supratrochlear passes forwards and upwards, and ends near the infratrochlear branch of nasal. This supratrochlear nerve is about 0·5 mm. in length.

The supraorbital branch of frontal passes backwards as well as upwards and outwards, and is about 0·8 mm. in length. The frontal nerve from its origin to its division is 1·0 mm.

The frontal nerve, near its origin, communicates with the fourth nerve by a stout branch. At the point where this communication takes place, the fourth nerve has just crossed the upper pole of the Gasserian ganglion, and lies to the inner side of the frontal nerve (fig. 8, Plate I.).

In connection with the frontal nerve is a collection of nuclei, which seems to represent a "ciliary" ganglion. The nuclei surround the frontal nerve, but more of them are placed to the inner than to the outer side of the nerve. The nuclei, which seem to be somewhat smaller than those of the cells of the Gasserian ganglion, are not very closely packed together in places, and at certain points the outline of the ganglion is not well defined. In the sections the ganglion has an oval shape, and encloses a section of the frontal nerve. The long axis of the ganglion extends from before backwards. The length of ganglion is 0·4 mm., width is 0·2 mm., and depth is 0·3.

The fourth nerve, at first lying to the inner side of the frontal nerve, also passes into this ganglion, but its fibres cannot be traced the whole way through it. Within the ganglion the fourth nerve is still observed to lie to the inner side of the frontal nerve.*

Although the frontal nerve in this way passes through the ganglion, none of its fibres wander out among the ganglionic cells. The nerve remains as a solid and distinct bundle as it traverses the ganglion.

The third nerve runs in much the same direction as the fourth nerve, but internal to it, and on a lower plane, and does not touch or communicate with this ganglion, but ends near the termination of the sixth below the optic stalk.

In this embryo, as in Ru, no upper division of the third nerve is present.

C.R.—Ophthalmic nerve = 0·24 mm.
Nasal branch = 1·5 mm.
Frontal branch = 1·0 mm.
Lachrymal nerve = 0·6 mm.
Supraorbital nerve = 0·8 mm.
Supratrochlear nerve = 0·5 mm.
Infratrochlear nerve = 0·2 mm.

Embryo F. M. (seven weeks, 17·5 mm.). Figures 9 and 10, Plate I.

The ophthalmic nerve is a short trunk arising from the Gasserian ganglion just in front of, and below, its upper pole. The direction of this trunk is upwards, forwards, and a little inwards, and it crosses the sixth nerve which turns obliquely

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* I was at first inclined to believe that this aggregation of nuclei, from its relation to the fourth nerve, represented a very early stage in the development of the superior oblique muscle of the eyeball.

forwards and outwards beneath it. To the inner side of the ophthalmic, the third nerve passes forwards and downwards, while the fourth nerve lies above it. The ophthalmic nerve after a course of 0·32 mm., divides into frontal and nasal branches. In the angle between these two the small upper division of the third nerve passes outwards and forwards.

The lower and nasal branch of the ophthalmic at first passes forwards and upwards, nearly parallel to the upper or frontal branch. Having crossed the optic nerve, the nasal nerve changes its direction, and turns inwards, running, at the same time, however, forwards and upwards. At the point where the nasal thus suddenly changes its direction, it gives off its infratrochlear branch, which, continuing the direction of the first part of the nasal trunk, ends near the inner part of the eyeball. This infratrochlear nerve is about 1·0 mm. long, and gives off a fine branch which runs downwards, and to the inner side of the eyeball. The nasal nerve, running inwards and forwards, and having given off its infratrochlear branch, then turns slightly upwards towards the brain, to the under surface of which, it comes into close proximity, just to the outer side of the olfactory nerves.

As the floor of the cranium is not marked off at this stage from the tissues below, it follows that the nasal nerve has, up to the present, not passed through any very compact tissue. The nerve now passes downwards and forwards to a point just below the groove at the root of the nose, and here, approaching the surface, the nerve traverses denser tissue. The nasal nerve, as it crosses the optic stalk, gives off two fine twigs, one of which runs along the outer, the other along the inner side of the optic nerve to the eyeball. The nasal nerve, from its origin to its termination, is 2·2 mm. in length.

The lachrymal nerve arises from the ophthalmic at the point where the nasal takes origin. This lachrymal is a fine nerve that passes, at first horizontally outwards, but afterwards ascends somewhat. It is at first some distance from the eyeball, but as it passes outwards it lies close to the equator of the eyeball. The lachrymal nerve communicates by a very fine twig with the posterior part of the orbital branch of the superior maxillary nerve. No trace of a lachrymal gland was detected. The length of the lachrymal nerve is 0·8 mm.

The frontal nerve is the upper thicker branch of the ophthalmic, and lies at its origin between the upper division of the third nerve below and the fourth nerve above. It communicates with the fourth nerve by a stout branch. The frontal nerve runs upwards and forwards, parallel to the nasal nerve, until the latter turns inwards; there also the frontal nerve changes its direction and turns outwards, but before it does so it gives off its supratrochlear branches. The supratrochlear nerve is represented by two twigs, which rising from the frontal where the latter changes its direction, are continued forwards over the eyeball towards the surface. These communicate with the infratrochlear branch of the nasal. The rest of the frontal nerve—supraorbital—passes outwards and upwards, and ends above the outer part of the eyeball. The twigs of the supraorbital do not seem to reach much higher than those of the supratrochlear, but are much more external. This nerve was probably not traced to its very termination.

In this embryo, notwithstanding its beautiful state of preservation, I was not able to make out with certainty anything about the ciliary ganglion. Large numbers of nuclei are present all round the different nerves as they lie close behind the eyeball, but no collection of these into a distinct isolated ganglion was discovered. I am inclined to believe that two collections of these nuclei, which, however, are continuous by a narrow neck of cells, but at no point sharply marked off from the tissue round, represent the ciliary ganglion. The first of these is present about the frontal branch, near its origin, while the other is placed between the inferior part of the third nerve and the nasal nerve. The fourth nerve is close to the upper collection.

In the orbital region it is exceedingly difficult to make out with certainty the outlines of the different structures which are here so crowded together. The muscles of the eyeball, which are now beginning to appear, increase this difficulty greatly, and the branches of the different motor nerves to these muscles also add to the confusion.

F.M.—	Ophthalmic trunk, . .	0·32 mm.	
	Nasal nerve, . . .	2·2 mm.	
	Frontal nerve, . . .	1·2 mm.	
	Lachrymal nerve, . .	0·8 mm.	
	Supraorbital, . . .	1·2 mm.	not fully traced.
	Supratrochlear, . .	1·4 mm.	
	Infratrochlear, . .	1·0 mm.	

Embryo Mr. (8th week).

In this embryo the nerves and muscles in the orbital region have practically, as we shall see, the disposition that obtains in the adult. The ophthalmic nerve springs from the anterior end of the Gasserian ganglion, and almost immediately divides into its branches. Indeed, the common trunk is so short that it can hardly be said to exist. The plane of the section is such that it cuts frontal and nasal branches transversely, and in section the transverse diameter of the frontal is at least double that of the nasal nerve. In this embryo the muscles of the eyeball are easily made out, and the termination of the motor nerves in the muscles are distinctly visible. As the nasal and frontal nerves pass forwards, the large third nerve passes downwards and forwards to their inner side. The sixth nerve, on the other hand, passes outwards below these two branches of the ophthalmic, and at once sinks into the external rectus muscle. The fourth nerve which passes inwards and downwards, to the outer side of, and a little behind the third, crosses over the top of the Gasserian ganglion, and then runs along the upper surface of the frontal. During this part of its course the fourth nerve is very closely connected with the frontal, it leaves the frontal finally by passing inwards to supply the superior oblique muscle. A small communication seems to exist between the third nerve and the undivided ophthalmic.

The nasal nerve is the smaller of the two nerves into which the ophthalmic divides. At first the nasal passes forwards beneath the frontal, whilst the trunk of the third nerve lies to its inner side. Soon the upper branch of the third nerve passes outwards in the angle between nasal and frontal nerves. Before, however, this branch of the third has crossed the nasal, the nasal itself has crossed the sixth nerve and come into contact with the ciliary ganglion. This ganglion lies below the nasal nerve, to the outside of, and behind the optic nerve. The nasal nerve when it leaves the ciliary ganglion, crosses the optic nerve lying very close to its upper surface. Beyond the optic nerve the nasal has a course downwards, forwards and inwards, to the interval between the superior oblique muscle and the internal rectus. Passing between these two muscles the nasal enters the interval between the vertical cartilage at the side of the nasal fossa, and the cartilage of the basis cranii. The nasal nerve now has a course to the outer side of the olfactory nerves, and then turns downwards as well as forwards, lying behind the plate of cartilage, which connects the mesial vertical plate with the lateral vertical lamina, developed in connection with the nasal fossa. The nasal nerve ends just above the opening of the nasal fossa on the face. The entire length of the nasal is 3·5 mm.

The infratrochlear branch which arises from the nasal just before the latter leaves the orbit is 1·3 mm. in length.

The frontal gives a small communicating branch which joins the nasal, just before the latter enters the orbital canal. Of the two terminal branches of the frontal, the supratrochlear passes forwards and downwards towards the surface, while the supraorbital passes forwards and upwards. The supraorbital is at least 3·0 mm. long, while the supratrochlear is about 1·6 mm. in length.

The frontal nerve passes almost horizontally forwards; it has, however, a slight inclination downwards and outwards. At first it lies between the nasal nerve below and the fourth nerve above, with the latter of which it communicates. In its course it comes to lie on the most posterior and internal part of the superior rectus muscle, and here it crosses the upper division of the third nerve. Just at this point the lachrymal is seen to take origin from the frontal, and pass horizontally outwards towards the surface of the head, above and to the outer side of the eyeball. The lachrymal nerve is 1·3 mm. in length. No lachrymal gland was found.

In Mr. the ciliary ganglion is a distinct collection of nuclei to the outer side of and behind the optic nerve. In section it presents an elongated figure, the long axis of which is vertical. Running forward through the extreme upper part of the ganglion is the nasal nerve, while fibres from the inferior division of the third nerve, which descends as it passes forwards, enter the ganglion from its inner side. From the ganglion some fine twigs run towards the eyeball both along the outer side of and below the optic nerve. The ciliary ganglion measures vertically 0·8 mm., from side to side 0·3 mm., and before backwards 0·2 mm.

A fine nerve comes from the upper and inner part of the anterior end of Meckel's ganglion in this embryo. This nerve turns upwards, and then outwards and a little forwards, and comes close to the ophthalmic artery and the optic nerve as these latter leave the cranium. This fine twig can be traced along the ophthalmic artery, and appears to end partly in the inferior division of the third nerve, and partly in the ciliary ganglion.

Mr.—Frontal nerve,	1·4 mm.
Supraorbital nerve,	3·0 mm.
Supratrochlear nerve,	1·6 mm.
Nasal nerve,	3·5 mm.
Infraorbital nerve,	1·3 mm.
Lachrymal nerve,	1·3 mm.

In three out of these five embryos, namely C.R., F.M, and Mr., it is easy to determine what particular nerves of the adult are represented by the nerves found in the embryo. Further it will be noticed that already in the human embryo at the beginning of the sixth week all the important branches of the ophthalmic nerve of the adult are represented, viz. frontal, with its supraorbital and supratrochlear branches; nasal, with its infratrochlear branch; and lachrymal.

In comparing embryo Ru. (5th week) with C.R. (beginning of 6th week) we are at once struck with the shortness of the frontal nerve in Ru. While the nasal nerve does not quite double its length in passing from the stage represented by Ru. to that of C.R., the frontal becomes more than ten times as long in C.R. as it is in Ru. It would seem that the nasal is the first formed branch of the ophthalmic, and that the frontal, which makes its appearance later, very soon overtakes it in length. That the frontal rather than the nasal is a direct continuation, as far as direction is concerned, of the main ophthalmic trunk in Ru. does not, as we shall see, make it unlikely that the nasal is the first representative of the ophthalmic nerve. A comparison of stage Br$_3$. (4 weeks) with Ru. (5th week) supports the view that the nasal represents the first formed ophthalmic division of the fifth nerve, for it will be seen that, in Ru., the sum of the length of the frontal, together with that of the common stem of the ophthalmic, does not equal the length of the nerve already present in Br$_3$., whereas it is evident that the nasal in Ru. can represent the nerve present in Br$_3$. The appearance of the posterior and shorter frontal branch, in Ru., is that of a nerve in a very early stage of its growth, *i.e.* it stains darker than it will later on, and more nuclei are present among its fibres. That the nasal is the first branch of the ophthalmic to make its appearance in the human embryo, corresponds with what may be observed in the rat. In this animal, also, the frontal nerve is formed later than the nasal, but its growth is more rapid. In a rat embryo of the 14th day the ratio of the length of the frontal to that of the nasal nerve is $\frac{18}{55}$, while on the 15th day the ratio is $\frac{5}{12}$.

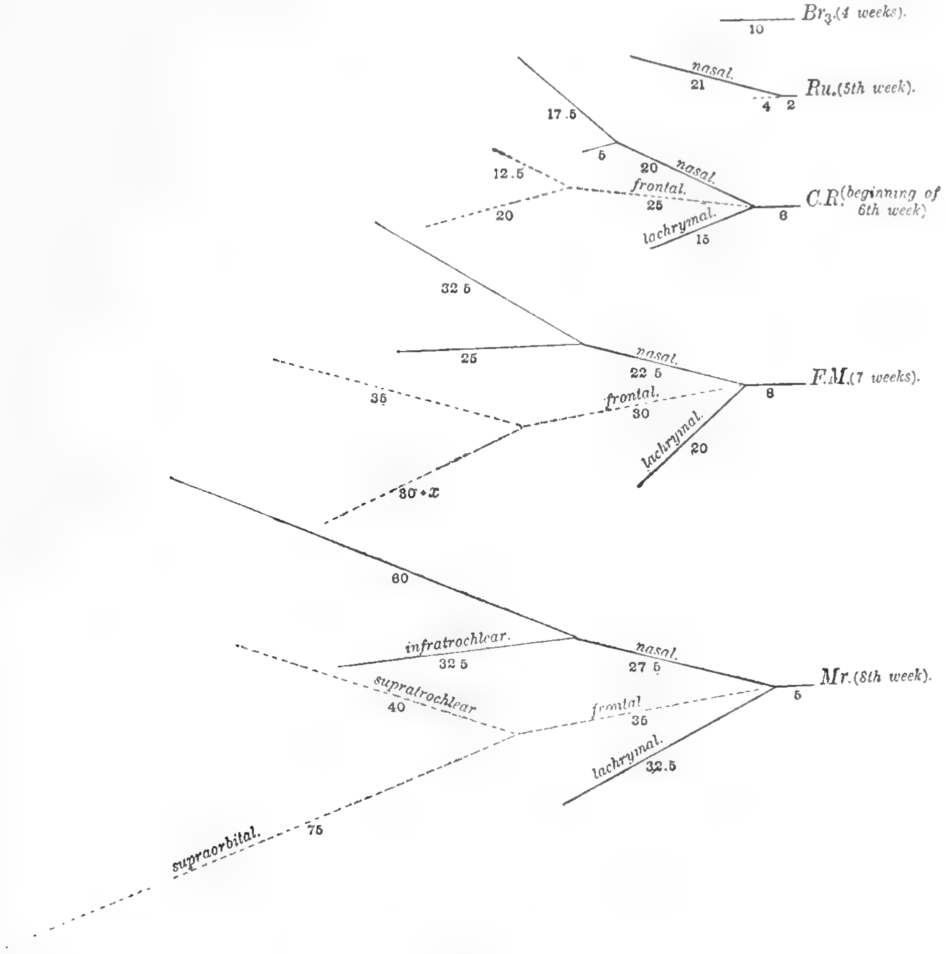

Figure 1.

Diagram to illustrate the relative lengths of the different branches of the Ophthalmic Nerve in five different human embryos The actual length of the nerves is in each case × 25 times and given in mm. No attempt has been made to represent the courses taken by the different nerves.

Milnes Marshall,* in his account of the development of the cranial nerves of the chick, describes an early stage of the ophthalmic nerve, and although he does not give it the name of "nasal," yet its course shows that it is undoubtedly that nerve. Hoffmann† has shown that in reptiles the naso-ciliaris, as he calls it, is at first larger than the frontal. We may state, then, that in birds, reptiles, and mammals, the nasal nerve appears before the frontal, and is the first representative of the ophthalmic division of the fifth cranial nerve.

In man the nasal and frontal are from the beginning branches of a common trunk; this is not so in the rat, as in this animal they at first rise separately from the Gasserian ganglion just as they do from the "ophthalmic" ganglion in reptiles, according to Hoffmann.

The marked communication between the fourth nerve and the frontal in C.R., and in the older stages is of interest, as it probably represents the communication described by Schwalbe‡ in the adult as existing between the fourth nerve and the trunk of the ophthalmic. Marshall and Spencer§ describe a communication between the fourth and the ophthalmic division of the fifth nerve in Scyllium, and a very intimate connection between the ramus ophthalmicus superficialis trigemini and the fourth nerve is also noted by Miss Platt,‖ in Acanthias, and by Dohrn,¶ in other Elasmobranchs. I have found this communication well marked in rat embryos, but in them, as in man, the communication is rather between the fourth and frontal nerves, than between the fourth and ophthalmic.**

The early development of the ciliary nerves, which are already present in F.M. (end of 7th week), is interesting. It is also instructive to note that not only is the lachrymal nerve itself present in C.R. (beginning of the 6th week), while the lachrymal gland is not developed until sometime in the third month, but that also the fine communication which exists in the adult between the superior maxillary division of the fifth nerve and the lachrymal nerve can already be traced in the embryo of seven weeks (F.M.).

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* "The Development of the Cranial Nerves in the Chick." Quarterly Journal of Microscopical Science, 1878, vol. xviii., p. 29.

† "Weitere Untersuchungen zur Entwicklungsgeschichte der Reptilien." Morphologisches Jahrbuch, 1886, Bd. xi., p. 207.

‡ "Lehrbuch der Neurologie," 1881, p. 825.

§ "Observations on the Cranial Nerves of Scyllium," Quarterly Journal of Microscopical Science, 1881, vol. 21, p. 472.

‖ "A Contribution to the Morphology of the Vertebrate Head, based on a study of Acanthias Vulgaris," Journal of Morphology, vol. v., 1891, p. 79.

¶ "Über die erste Anlage und Entwicklung der Augenmuskelnerven bei Selachien und das Einwandern von Medullarzellen in die motorischen Nerven," Mittheilungen aus der Zoologischen Station zu Neapel, 1891, Bd. 10, p. 1.

** In "Quain's Anatomy," Part II., vol. iii., p. 233, a communication between the fourth and frontal nerves is noted on the authority of Berté.

The above diagrams (fig. 1) show that in the embryo, as one would expect, growth takes place chiefly at the distal end of the developing nerve. A nerve once formed, no doubt, increases in length, but, probably, only in proportion to the growth of that part of the embryo in which it lies. At the distal end, however, growth is much more rapid, and so the nerve wanders out into new territory. The frontal and nasal nerves in C.R., F.M., and MR., offer good examples of this. We notice that in passing from one of these stages to the next the frontal or nasal nerve may increase by 10 to 20 per cent. of its original length, while the increase noted for their terminal branches (supraorbital, supratrochlear, nasal proper and infratrochlear) varies from 30 to more than 100 per cent.

For the embryos C.R. and F.M. it seems probable that the diagrams exaggerate the length of the undivided trunk of the ophthalmic nerve.

In a series of sections, cut more or less obliquely through a dividing nerve, it must necessarily be difficult to determine accurately the precise point at which the division takes place. This is the case in both these embryos. In MR. on the other hand the sections cut the ophthalmic nerve at right angles to its direction, and the point of division can therefore be determined with precision. This probably explains why the ophthalmic trunk appears shorter in MR., than in C.R. and F.M. It is just possible, however, that in MR. there is a real shortening of the trunk, due to a forward growth of the Gasserian ganglion absorbing, as it were, a portion of the nerve. Whilst this may be suggested as a possible explanation, there is absolutely no proof that the Gasserian ganglion shifts its position in this manner.

The study of the nasal and other branches of the ophthalmic nerve in the embryo affords an explanation of the complications observed in certain parts of their course in the adult. Professor His* gives an account of how the courses of nerves in the embryo are modified by the bending of the tissues in which they lie, and by their meeting with obstacles in their growth outwards. Many of the factors referred to by Professor His, as determining the course of nerves, are illustrated by the growth of the branches of the ophthalmic nerve. Starting with embryo BR$_3$., we observe in it a nerve which has a course upwards, and a little inwards, behind the eyeball (fig. 5, Plate I.). This nerve, as we have seen, represents the nasal of the adult, and its direction corresponds to the direction assumed by the processes of the neuroblast cells of the Gasserian ganglion from which the fibres of the nasal nerve arise.

In RU. the course of the ophthalmic nerve is at first upwards, but the direction of the nasal nerve is mainly forwards (fig. 6, Plate I.).

This change in the direction of the nasal nerve seems to receive explanation by a growth forwards of the cerebrum, which, of course, carries with it the

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* "Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim menschlichen Embryo." Abhandlungen der Königl. Sächs. Ges. d. Wissensch. 1888, Bd. xiv., p. 386.

tissues surrounding it, deflecting or bending the primitive nasal nerve in $\text{B}\textsc{r}_3$. The course of the frontal nerve in this and the next embryo bears out this explanation. In RU. the frontal nerve has just appeared and is growing very rapidly. Its fibres growing out from cells of the Gasserian ganglion, after the more distal part of the nasal nerve has been bent forwards, run at first with the nasal fibres, forming with them a common trunk, but at the point where the nasal fibres bend forwards, the frontal fibres pass on as an independent nerve, and maintain the upward course of the common trunk for a short time. The upward course of the frontal fibres is, however, soon arrested; they also become bent in a forward direction, to form a nerve running above and parallel to the nasal, as we have observed in C.R. (figs. 7 and 8, Plate I.). The late appearance and rapid growth of the frontal fibres probably explains the direct course taken for some time by the frontal nerve. The first direction taken up by a nerve will be determined in part by the primitive direction assumed by the neuroblast fibres, and in part by the unequal growth of the tissues through which the nerve is passing; once, however, the fibres have been deflected, and have, for any reason, taken up a new course, these fibres will continue in this new direction, unless they are again deflected by unequal growth, or meet with a barrier through which they cannot pass. The turning inwards of the nasal nerve in C.R., near its termination, would seem to depend on the fact that while the distance between the nasal nerves of opposite sides, at their origins in C.R. is 0·5 m.m. greater than in RU., yet the distance between the summits of the nasal pits is actually greater in RU. than it is in C.R., owing to the approximation of nasal fossæ towards the mesial plane, in the older stages. In this way, then, at the level of the nasal nerves, at all events, the head of the embryo, at this time, is increasing in width more posteriorly than in front. A separation of the proximal ends of the nasal nerves, without a corresponding separation of their more distal parts, will, of course, give the nerves a direction inwards. The nasal nerves finally turn downwards, their direction being determined by the growth downwards of the tissues to form the nose.

The frontal nerves, placed at a higher level than the nasal, and passing close to the under surface of the cerebrum, do not become deflected inwards, but are on the other hand turned outwards, and follow the outward and upward growth of the hemisphere of the cerebrum.

The infratrochlear branch of the nasal nerve comes off at the point where the nasal turns inwards, and continues at first, the direction of the main trunk. This would seem to show that the fibres which form this nerve grow out from the Gasserian ganglion at a later period, or, perhaps, at a slower rate than those of the nasal proper, and so escape the bending inwards experienced by the nasal fibres. In their growth the fibres of the infratrochlear leave the main nerve where it is sharply bent. It should be noted that in figure 8, Plate I., this point is not brought out. If this be a correct explanation, we would expect that the fibres which will ultimately form an independent branch would take, in the first instance, the same direction as the parent trunk, and further, that these fibres would leave the main trunk to form the branch at the point where the trunk is sharply bent. The branch when formed, will at first be, as far as direction goes, the continuation of the undivided nerve. Examples of this are afforded by the infratrochlear branch of nasal, the supratrochlear branch of frontal, and by the frontal itself. We have here another cause for the branching of nerves besides those enumerated in the paper already referred to, in which Professor His lays stress on the fact that nerves meeting with such obstacles as small vessels, cartilages, &c., must necessarily divide or be deflected, as well as on the fact that in any nerve the fibres from the beginning do not run parallel to one another, and so in their growth outwards may separate, and thus give rise to branches.

Professor His* has called attention to the fact, that although the nasal or nervus ethmoidalis is the special nerve of the fronto-nasal process, yet it is not distributed in the adult to the whole region derived from this part of the embryo, but that branches of other nerves encroach upon its domain. Thus we find branches of the infraorbital nerve supplying not only the lateral but also the central part of the upper lip, which owes its origin to the fronto-nasal process. Professor His also points out that the ophthalmic nerve fails to completely fulfil the rôle of a dorsal branch rightly ascribed to it by Gegenbaur, and that it is assisted by branches from the second and third cervical nerves.

The comparatively late development of the frontal nerves probably corresponds with the late appearance of the cerebral hemispheres, the protective coverings of which they supply.

Marshall and Spencer first directed attention to a ganglion which they discovered on the ramus ophthalmicus profundus in Scyllium.† This ganglion they consider represents the ciliary ganglion, and seeing that they followed Schwalbe in referring the ciliary ganglion to the third nerve, they are forced to consider the ramus ophthalmicus profundus a part of the third nerve. They point out that the proximal part of the ramus profundus is from the first simply a connecting nerve between the ciliary ganglion and the Gasserian; and that therefore "there is no reason whatever in the early stages for considering it as belonging to the fifth rather than to the third nerve." These authors do not describe any stage early enough to show whether the fibres of this connecting nerve start from the "ciliary" ganglion and grow towards the Gasserian, or

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* "Die Morphologische Betrachtung der Kopfnerven." Archiv für Anatomie und Physiologie. Anat. Abtheilung, 1887. Heft vi., p. 447.

† "Observations on the Cranial Nerves of Scyllium." Quarterly Journal of Microscopical Science, 1881, vol. xxi.

whether they grow out in the opposite direction from the Gasserian towards the "ciliary" ganglion. They assume, however, that the nerve belongs to the "ciliary" ganglion, and hence to the third nerve. They further remark that the ramus ophthalmicus profundus clearly represents the nasal nerve of mammals—an observation which has received confirmation from a large number of more recent writers. It must be noted, however, that according to Marshall and Spencer this nerve, if it represents the nasal of mammals, passes under the internal rectus as well as under the superior rectus and superior oblique muscles in Scyllium (p. 29).

Marshall and Spencer thus separate in Scyllium the nasal nerve from the rest of the ophthalmic division, and refer it to a distinct ganglion, which they call "ciliary."

That they are right in doing this has been borne out by the observations of a number of more recent investigators. They only err in so far that they ascribe their "ciliary" ganglion, and with it the ramus profundus, to the third nerve.

Beard* has shown that the ganglion discovered by Marshall and Spencer is not the true ciliary ganglion, nor yet the ganglion of the third nerve. The ganglion of Marshall and Spencer gives origin to the fibres of the ramus profundus. Beard who had formerly followed Marshall and Spencer, and Van Wijhe in calling this ganglion "ciliary" proposes now for it the name "mesocephalic." He says: "The mesocephalic ganglion is the ganglion of a posterior root of a cranial nerve; it is the homologue of the Gasserian, facial, or glosso-pharyngeal ganglion. Its only nerve at the present time is the ophthalmicus profundus. The ciliary ganglion is developed much later than the segmental cranial ganglia, and is not the ganglion of a posterior root of a cranial nerve; it probably belongs to the sympathetic" (page 575).

Van Wijhe first clearly demonstrated, according to Beard, that in Elasmobranchs the ganglion on the ramus profundus was the ganglion of a posterior nerve-root, unlike Beard however, he retained the term "ciliary," although he knew that it did not represent the ciliary ganglion of the adult, or ganglion oculomotorii, as he called it. Beard's Paper is a very important one, as he makes very plain the separation between the ganglion of the ramus profundus and the ciliary. He states that what is found in Elasmobranchs is practically reproduced in the chick. On the other hand, "in amphibians, and very probably in all mammals, certainly in man, the mesocephalic ganglion is partly fused from the start with the Gasserian, and only appears as a blunt process of the latter as figured by His" (page 567).

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* "The Ciliary or Motoroculi Ganglion and the Ganglion of the ophthalmicus profundus in Sharks." Anatomischer Anzeiger, 1887, p. 565.

Before the appearance of Beard's paper, Hoffmann* had described for reptiles the trigeminal ganglion, as being divided into two great masses which lie close together, but more or less distinct from one another. From the front ganglion the ophthalmic nerve arises, from the posterior one, the other two divisions of the fifth nerve. Hoffmann has no doubt but that this anterior ganglion in reptiles—the ganglion ophthalmicum as he calls it—is the homologue of a spinal ganglion (page 206). Hoffmann describes not only the nasal, but also the frontal, nerve as a branch or outgrowth of the ophthalmic ganglion (mesocephalic of Beard). In this way then reptiles seem to differ from Elasmobranchs, since in the latter the nasal alone arises from the separate ganglion. Hoffmann further brings out the important fact that the nasal nerve is at first larger than the frontal in reptiles.

In the forms studied by Beard, Van Wijhe, and others, the mesocephalic ganglion and its roots, soon become fused with the Gasserian ganglion and the roots of the fifth nerve. From the very first, the distance between the two is very short. The result of this fusion is that the ramus profundus then appears to be a branch of the trigeminal nerve.

Ewart† has given an account of these nerves in the adult in certain Elasmobranch fishes.

In Læmargus he finds that the ophthalmicus profundus possesses a root, a root ganglion, and a trunk which gives off a number of well-marked branches. The nerve takes origin from the side of the medulla, immediately in front of the fifth nerve, and at first is partly blended with the fifth. Outside the cranial wall a special ganglion is present on the nerve—the mesocephalic of Beard—which lies dorsal to, but only a slight way in front of, the Gasserian ganglion. From this ganglion a nerve passes forwards, having the same relations to the ocular muscles as the nasal presents in man.

In Raia the ganglion of the ramus profundus lies some distance in front of the Gasserian ganglion, and nearer to the third nerve than in Læmargus.

In Torpedo,‡ on the other hand, the ganglion of the ramus profundus lies in close contact with the Gasserian. This author also states in another place§ that in Elasmobranchs the ramus profundus, which evidently represents the nasal nerve in man, is neither a branch of the third nerve nor of the trigeminal. The ramus profundus belongs to a ganglion called by him the profundus or oculonasal ganglion, which is identical with the mesocephalic ganglion of Beard.

* "Weitere Untersuchungen zur Entwicklungsgeschichte der Reptilien," Morphologisches Jahrbuch, 1886, Bd. xi., p. 202.

† "On the Cranial Nerves of Elasmobranch Fishes," Proceedings of the Royal Society, 1889, vol. xlv., p. 524.

‡ "On the Cranial Nerves of Torpedo," Proceedings of the Royal Society, 1890, vol. xlvii., p. 290.

§ "On the Development of the Ciliary or Motor Oculi Ganglion," Proceedings of the Royal Society, 1889, vol. xlvii., p. 287.

Ewart considers that he has proved the existence of this oculo-nasal ganglion in a five-months human fœtus, in which he has found a collection of cells lying under cover of the inner portion of the Gasserian ganglion. It seems more probable from my observations that what he has found in this fœtus represents a cellular connexion, which exists in the embryo, between the otic and Meckel's ganglion, and which has the position described. This will be discussed again when we come to consider the otic and Meckel's ganglion.

It is then quite certain that in Elasmobranchs, at all events, the nasal nerve or ramus profundus is primitively not a branch of the Gasserian ganglion, but that it is a separate nerve with a separate ganglion, and that it may persist as such even in the adult of some forms (Ewart).

The independent nature of the nasal nerve is not, however, a peculiarity of Elasmobranchs, as a number of observers have described it, having a more or less similar origin in a variety of other animals.

Thus Shipley,* Scott,† Ahlborn,‡ Kupffer,§ and others have described the special ganglion of the ramus profundus in Marsipobranchii either for the embryo or for the adult, while Kupffer‖ also describes similar conditions in Ganoidei (Accipenser). In Reptilia we have the observations of Hoffman¶ on this point; and in Aves those of Beraneck.** According to the observations of Plessen and Rabinovicz,†† Salamandra maculata forms an exception, as these authors state that in this animal, although two distinct ganglia are present for the fifth cranial nerve, the nasal and mandibular nerves arise from the main ganglion, while the fronto-maxillaris takes origin from the accessory one. The observations of Wiedersheim‡‡ and Kingsley§§ in other amphibia do not agree with those of Plessen and Rabinovicz; further, Oliver Strong‖‖ has recently stated that Plessen and Rabinovicz have mistaken a ganglion, which really belongs to the superficial ophthalmic and buccal branches of the seventh nerve, for an accessory ganglion of the trigeminal.

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* "Some points in the Development of Petromyzon Fluviatilis," Quarterly Journal of Microscopical Science, vol. xxvii., p. 325, and fig. 22, plate XXVII.

† "Embryology of Petromyzon," Journal of Morphology, 1887, vol. i., p. 278, and fig. 40, plate XI.

‡ "Über den Ursprung und Austritt der Hirnnerven von Petromyzon," Zeit. für wiss. Zool., 1884, Bd. xl., p. 286.

§ "Studien zur vergleichenden Entwicklungsgeschichte des Kopfes der Kranioten," München, 1894, Heft. ii., p. 72. See also Heft. iii. "Die Entwicklung der Kopfnerven von Ammocoetes Planeri," which has appeared since this paper was written.

‖ *Loc. cit.*, p. 72.

¶ "Weitere Untersuchungen zur Entwicklungsgeschichte der Reptilien," Morphologisches Jahrbuch, 1886, Bd. xi.

** "Étude sur les replis medullaires du Poulet," Recueil Zoologique Suisse, 1888, vol. iv., p. 337.

†† "Die Kopfnerven von Salamandra maculata," München, 1891, p. 8.

‡‡ "Lehrbruch der vergleichenden Anatomie," Jena, 1886, p. 338.

§§ "The head of an Embryo Amphiuma." The American Naturalist, August, 1892, p. 677.

‖‖ "Cranial nerves of Amphibia." Journal of Morphology, vol. x., 1895, pp. 162, 108.

According to this last author, in amphibia, a "partial division of the anterior extremity of the Gasserian ganglion is the only sign of separation between the ganglion of the Rr ophthalmicus and maxillo-mandibularis trigimini respectively."

When now we attempt to compare what is found in these lower animals, with what is known for man, we find that Professor His describes the condition of the Gasserian ganglion in an embryo in which only the rudiments (Anlagen) of the ganglia are present, the nerve roots not yet having appeared, as follows* :—

"Die obere Ecke des Ganglions verlängert sich in einen Strang welcher an die Augenblase herantritt, das vorderste Ende desselben kommt als Anlage des G. ciliare über den Stiel der Augenblase zu liegen"; and again, writing of the Gasserian ganglion, he says† :—"Von seinem vorderen Ende erstreckt sich ein verjüngter Fortsatz bis hinter die Augenblase, als Anlage des G. ciliare." Beard,‡ referring to this description and the figure given by Professor His, says:—"From the above account and the examination of the figures given by Professor His, I do not entertain the slightest doubt that what he thus describes is really the rudiment (Anlage) of the mesocephalic ganglion."

Professor His,§ writing more recently still, considers that the ganglion described by him is the same as that seen by Marshall, Schwalbe, and others, and that it represents the ciliary ganglion. He states that Beard is wrong in calling it mesocephalic, and that in man, at least, the fibres of the ophthalmic division of the fifth nerve are not derived from its cells. "Das Ganglion ciliare als solches entwickelt sich aus dem Gesammt-complex der Trigeminusganglien als dessen vorderster, der Augenblase anliegender Theil. Man könnte dasselbe kurzweg als das Stammganglion des R. ophthalmicus bezeichnen, falls sich erweisen liesse, dass die Fasern des letzteren ganz oder doch zum grösseren Theil aus seinen Zellen entstehen. Dies ist indessen beim Menschen sicherlich nicht der Fall, bei welchem die lange Wurzel des Ganglions den Maximalbetrag von Fasern ergiebt, denen das G. ciliare als Ursprungsort zugetheilt werden kann."

Beard's ganglion being the homologue of a ganglion on a posterior nerve root cannot then be represented by this forward prolongation of the Gasserian ganglion in man. From my observations on Professor His's specimens, I believe that the ganglion of the nasal, or ramus profundus, if it exists at all in man, is so completely fused with the Gasserian ganglion, that the nasal and frontal nerves appear simply as branches of the latter. Further, it appears to me that the forward projection

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* "Anatomie Menschlicher Embryonen." Part I., p. 106. See also fig. A1, plate VII. of Atlas.

† Page 44.

‡ "The Ciliary or Motor Oculi Ganglion, and the Ganglion of the Ophthalmicus Profundus in Sharks." Anatomischer Anzeiger, 1887, p. 567.

§ "Die Morphologische Betrachtung der Kopfnerven." Archiv für Anatomie und Physiologie. Anat. Abtheilung, 1887. Heft vi., p. 421.

of the Gasserion ganglion cannot represent the ciliary ganglion of the adult. My observations go only as far back as the end of the fourth week (embryo $\mathrm{B{\scriptstyle R}}_3$.), at which time I believe the Gasserian ganglion has a rounded upper, or anterior end, from which a relatively thick nerve, with many nuclei among its fibres, passes upwards. This nerve, which represents the nasal, takes origin from a point in front of the summit of the ganglion. Professor His,* in a description of the nerves of this same embryo describes and figures a ganglion on the ophthalmic nerve.† I have not, however, been able to find any definite collection of cells which might represent it. At my request Professor His has, with great courtesy again examined the sections, and has been so kind as to write me a letter in which he says that the description written in 1888 corresponds to his opinion at the time, but that now he finds it difficult to determine whether the nuclei present represent ganglion cells, or belong to the nerve sheath. Since I was unable to satisfy myself of the presence of a ciliary ganglion in Ru., a still older stage than $\mathrm{B{\scriptstyle R}}_3$., I believe that the nuclei present among the fibres of the ophthalmic nerve in the latter, cannot represent a ciliary ganglion, but rather that they represent the cells of the so-called "nervenführendes Gewebe," which appears before the axis-cylinders of the nerves are present, and from which the nuclei of the white substance of Schwann are said to be developed. A cellular stage in the ophthalmic nerve is described by Béraneck‡ for the chick embryo and also by Goronowitsch,§ who, however, does not consider true nerves to be present until axis-cylinders are formed. Kuffer‖ also described these cellular tracts in Petromyzon, and other authors have mentioned them in various other lower animals.

In a rat embryo of the twelfth day the Gasserian ganglion is found to have a rounded upper end from which a cellular cord passes up behind the eyball, a distance of 0.1 mm. The cells of this cord do not seem to differ much from those of the ganglion itself. The cord does not, as figured by Professor His for his human embryo A, end in a swollen extremity. No fibres were detected among the cells of this cord. Also in this embryo the two other divisions of the fifth nerve are present, and possess some fibres in them, and are thus farther advanced than in Professor His's embryo A. In a rat embryo, just a little more advanced

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* "Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim Menschlichen Embryo," Abhandlungen der Königl. Sächsischen Gesellschaft der Wissenschaften, Bd. xiv., 1888, p. 372, and fig. 4, plate II.

† Professor F. Mall has also described a ciliary ganglion as present on the ophthalmic division of the fifth nerve in a human embryo of 26 days. Journal of Morphology, vol. v., p. 495, 1891.

‡ "Étude sur les Replis Médullaires du Poulet," Recueil Zoologique Suisse, 1888, vol. iv., p. 336.

§ "Untersuchungen über die Entwicklung der sog. 'Ganglienleisten' im Kopfe der Vögelembryonen," Morphologisches Jahrbuch, 1893, Bd. 20, p. 187.

‖ "Die Entwicklung von Petromyzon Planeri," Archiv für Mikroskopische Anatomie, 1890, Bd. 35. See also "Studien zur vergleichenden Entwicklungsgeschichte des Kopfes der Kranisten," Heft. iii. München, 1895.

than the last one, we have, in place of the cellular cord, a tract in which some fibres are present, although many cells still remain. In an embryo a little longer still, we find a better marked nasal nerve, and the frontal, which is now beginning to develop, is in a condition very like that in which we have seen the nasal in the second stage, *i.e.* it is represented by a tract chiefly composed of cells, but with a few fibres among them. As the fibres of the nerves increase in number, the nuclei are found in section more on the outside, while the fibres are collected towards the centre.

In the rat, therefore, as in man, nasal and frontal nerves are branches of the Gasserian ganglion. In both cases we have, at first, relatively a large number of nuclei present among the nerve fibres. Later on these disappear. A ganglion for these nerves, distinct from the Gasserian, does not exist in the human or rat embryos. The forward cellular prolongation of the Gasserian ganglion, described by Professor His, does not represent such a ganglion as Beard has suggested. The ciliary ganglion of the adult is not present in a recognisable form at the time of origin of these nerves.

In the guinea-pig, Professor G. Chiarugi,* describes an early stage in which there is a distinct ophthalmic ganglion forming later a conical bed on the Gasserian ganglion, and from whose apex the ophthalmic nerve arises. This ophthalmic ganglion later fuses completely with the Gasserian ganglion. It probably represents the cellular cord which I have described in the rat embryo, which, however, disappears as the fibrous ophthalmic nerve is formed.

It is, indeed, unfortunate that Minot in his description not only considers that the ganglion described by Professor His represents the ciliary ganglion of the adult, but also states that it gives origin to the fibres of the ophthalmic nerve. On page 641 of his "Human Embryology," referring to the fifth cranial nerve, he remarks:—"Its ganglionic portion is double, comprising the ciliary or ophthalmic ganglion and the Gasserian." Then, on page 642, under "ganglion ciliare," we find:—"This is the ganglion which has been long and generally known as the ciliary, and becomes the ciliary of the adult . . . The centrifugal nerve, arising from the ganglion, is known as the ramus ophthalmicus profundus, the centripetal nerve as the radix longa, which joins the trigeminal ganglion before the radix enters the brain . . . Why the fibres pass to the brain by way of the trigeminal, instead of making an independent entrance, is unknown."

Professor His has stated, as we have seen above, that the ganglion which he described as ciliary in man did not give rise to fibres of the ophthalmic nerve, and further, the proved structure of the ciliary ganglion in the adult shows that it is not the homologue of a spinal ganglion. This will be mentioned more fully at a later stage.

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* Monitore Zool. Ital. v., 1894, pp. 275–280.

Since the ramus ophthalmicus profundus of Elasmobranchs represents the nasal of mammals, it is interesting to inquire whether there is any nerve in Elasmobranchs to represent the frontal of mammals. Marshall and Spencer describe the ophthalmic branch of the fifth nerve in Scyllium as lying "dorsal to all the eye muscles and other contents of the orbit." This ophthalmic branch of the fifth in Scyllium rises from the Gasserian ganglion directly; and, though in the embryo at first perfectly distinct, it is in the adult more or less closely united with the ophthalmic branch which the seventh cranial nerve in these animals sends into the orbit. This ophthalmic branch of the trigeminal is also described by Ewart for Læmargus and Raia, and, so far as I know, no attempt has been made to separate it from the fifth nerve as has been done for the ramus profundus. Ewart says that in Læmargus it rises sometimes from the fifth nerve trunk, sometimes from the mandibular division. In Raia the fifth nerve is described as dividing into maxillary and mandibular branches, and sending off a small superficial ophthalmic branch as well. This superficial ophthalmic branch of Elasmobranchs may represent the frontal of mammals, and its small size in the former would correspond with the small size of the cerebrum in these animals compared with that of mammals, the protecting covering of which the frontal nerves supplies. If this is so, we have the fourth nerve in Elasmobranchs communicating with the frontal in exactly the same way as is found in the different stages of the human and rat embryos.

In reptiles, on the other hand, Hoffmann has described the frontal as well as the nasal as arising from the ganglion ophthalmicum, and he mentions no communication between the fourth and frontal nerves; and we must also note that the nerve which Strong* describes in amphibia, as arising from the partly segmented off, anterior end of the Gasserian ganglion, apparently represents the whole of the ophthalmic nerve.†

The short preliminary account given by Chiarugi‡ for the guinea-pig is not sufficient to show whether the nasal and frontal nerves are distinct at their origin in this animal.

Ciliary Ganglion.

We have seen that in $\mathrm{B{\small R}}_3$. (4 weeks) and in RU. (5th week) no ganglion except the Gasserian was found in connection with the ophthalmic nerve. In C. R. (beginning of 6th week) however, a distinct ganglion was found in connection with the frontal branch of the ophthalmic. The cells of this ganglion are not in contact with the nasal nerve which lies at a lower level, although they are not far

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* "Cranial Nerves of Amphibia." Journal of Morphology, vol. x., 1895.

† The same appears to be the case in Ammocœtes Planeri. Kupffer.

‡ Monitore Zool. Ital. v. (1894). Noticed also in Journal of Royal Microscopical Society, October, 1895, p. 507.

from it (fig. 8). The third nerve does not touch the ganglion, while the fourth, on the other hand, runs into it. In embryo Mr. (8th week), a large ganglion is present, connected above with the nasal nerve, and below with the third, and occupying a position corresponding to that of the ciliary ganglion of the adult. In this embryo no ganglion was found on the frontal nerve. It seems then, as if the ganglion present in C. R., in connection with the fourth and frontal nerves has, by a migration of its cells, come in Mr. into relation with the third and nasal nerves. This explanation is not inconsistent with the imperfect observations made on F. M. (7 weeks), a stage intermediate between C. R. and Mr. (page 28).

The structure and origin of the ciliary ganglion in different groups of animals has long occupied the attention of a number of observers, and most conflicting accounts have from time to time been published, not only regarding its origin, but also in regard to the cells which compose it. By some authors the ciliary ganglion has been described as the equivalent of a spinal ganglion, and as belonging to, the third nerve, to the ophthalmicus profundus, or to the ophthalmic itself. Others, again, have described the ganglion as being purely sympathetic, or as being composed of two distinct portions, one apparently sympathetic, the other equivalent to a spinal ganglion.*

Schwalbe,† as is well known, first attempted to prove an homology between the collections of ganglionic cells, found in various animals, in the course of the third nerve, with the ciliary ganglion of the human adult. He came to the conclusion that the ciliary, which he called ganglion oculomotorii, was the equivalent of a spinal ganglion, and that its proper connection with the brain was the third nerve. Schwalbe has really only proved the existence of nerve cells in the course of the third nerve of many animals, and his supposition that the ciliary ganglion represents a spinal ganglion has not been borne out. Schwalbe has, however, had many followers in assigning the ciliary ganglion to the third nerve. Much more recently on quite different grounds, and in a totally different manner the ganglion has been referred to the third nerve. I believe that my observations prove that the ciliary ganglion in man, when it is first recognisable, has no connection whatever with the third nerve. With regard to the connection of the third nerve with a ganglion, Professor His says‡—"Es ensteht der Oculomotorius als ein rein motorischer Nerv und als solcher hat er kein angebornes Recht auf

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* For an account of recent Papers on the ciliary ganglion, see Dohrn, "Über die erste Anlage und Entwicklung der Augenmuskelnerven bei Selachier und das Einwandern von Medullarzellen in die motorischen Nerven," Mittheilungen aus der Zoologischen Station zu Neapel, 1891, Bd. x., p. 1.

† "Das Ganglion oculomotorii," Jenaische Zeitschrift für Naturwissenschaft, 1879, Bd. xiii. Also "Lehrbuch der Neurologie," 1881, p. 819.

‡ "Die Morphologische Betrachtung der Kopfnerven," Archiv für Anatomie und Physiologie. Anat. Abtheilung, 1887, Heft. vi., p. 421.

ein Ganglion." Professor His, on the other hand, has always looked on the ciliary ganglion as the extreme anterior end of the trigeminal complex, which becomes cut off from the rest of the ganglion of the fifth.

For my own part, I believe that the cells which lie in front of the Gasserian ganglion either abort entirely or form the "nervenführendes gewebe" of Goronowitsch, through which the axis-cylinders of the nerve cells of the Gasserian ganglion grow out to form the ophthalmic nerve. Beard considers that the cellular mass described by Professor His represents his mesocephalic ganglion and not the true ciliary ganglion which is a later formation. We have already noted that Professor His's description clearly indicates that the anterior blunt process of the Gasserian ganglion cannot represent Beard's mesocephalic ganglion.

When now we inquire how the ciliary ganglion arises in lower animals we find that Hoffmann,* in reptiles, described it as a bud or outgrowth from the ophthalmic ganglion (mesocephalic of Beard). This outgrowth becomes less intimately connected with the ophthalmic, and more and more closely bound to the third nerve, in the older stages. Finally, it appears to belong to the third nerve. Ewart†, in Elasmobranchs, describes practically a similar origin for the ciliary ganglion. Ewart, Beard, Hoffmann Van Wijhe, and others testify to the late appearance of the ganglion, and Hoffmann and Ewart, at all events, look on its cells as derived from the trigeminal complex. In man the ciliary is certainly a late formation, but where its cells are derived from is uncertain.

Dohrn,‡ apparently, takes quite a different view; he considers that the cells of the ciliary ganglion migrate from the brain along the course of the third nerve. Unlike Ewart, he has found in Elasmobranchs cells in the course of the third nerve, and has seen and figured such migrating from the brain. He calls attention to the fact that ganglionic nerve cells have been demonstrated in the course of other motor nerve roots by Thompsen, Schäfer and others. Goronowitsch has also found these cells in the course of the third nerve, and believes that it is highly probable that they are the source of cells of the ciliary ganglion. Dohrn and Goronowitsch then agree in referring the ciliary ganglion to the third nerve, but not in the sense of a ganglion on a posterior nerve root.

Goronowitsch states that Professor His's description and figure of the "ganglienleiste" for the chick is correct, and that the description is only erroneous when it states that the Gasserian and ciliary ganglia arise directly from the anterior segment of this structure. According to Goronowitsch, the whole anterior part of

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* "Weitere Untersuchungen zur Entwicklungsgeschichte der Reptilien," Morphologisches Jahrbuch, 1886, Bd. xi.

† "On the development of the Ciliary or Motor Oculi Ganglion." Proceedings of the Royal Society, vol. xlvii., 1889, p. 287.

‡ Mittheilungen aus der Zoologischen Station zu Neapel, 1891. Bd. x.

the "ganglienleiste" becomes changed into mesenchyme, before the ganglia of the fifth nerve appear. The ciliary ganglion is formed by cells migrating into the course of the third nerve from the brain.*

Sedgwick,† in his attack on the cellular theory of development, describes for Elasmobranchs, conditions practically similar to those given by Goronowitsch for the chick.

He states—"The nerve crest does not, as was first stated by Balfour, and afterwards by all authors, on the development of nerves, give rise exclusively, or even principally, to nerves and ganglia. It gives rise to nuclei, which spread out in and add to the mesoblastic reticulum, which, at all times, *i.e.*, from the very beginning, exists between the layers, and to nuclei, which become the nuclei of rudiments of the nerve ganglia."

We must now inquire what, according to these two authors, is the origin of the ganglia and the nerves connected with them. According to Goronowitsch, before true nerves—axis-cylinders processes—or ganglia appear, in the case of the fifth nerve two processes of cells become differentiated from the mesenchyme round about. These two processes meet together in a common cellular mass, and are not true nerves, but simply cellular cords, differentiated from the rest of the mesoblast. From them the sheaths of the true nerves, which appear later, will be developed; into one of the cords the neuroblast fibres of the ophthalmic nerve will later on grow out, into the other, those of the inferior maxillary nerve. No cord of cells is at first present to represent the superior maxillary nerve. The cells of the ganglia arise far away from the medullary canal, in the region of the "Froriepschen anlagen."

Sedgwick, for Elasmobranchs, describes certain parts of the neural crest (ganglienleiste) as remaining "unaltered and characterised by a greater density of nuclei," while the greater part of it breaks up into a reticulum called mesoblast. These unaltered tracts "mark the course of the future nerves and the sites of the future ganglia."

"The Gasserian ganglion, the ophthalmicus profundus, the mandibular branch of the fifth, and the ciliary ganglion (mesocephalic of Beard) thus emerge from the remains of the nerve crest, are so to speak crystallised out of it" (p. 96). Like Goronowitsch, he compares the neural crest to the primitive streak—a centre for the growth of nuclei. Unlike Goronowitsch, he does not believe in the neuroblasts of His, for "the nerves are laid down before any nerve cells are

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* "Untersuchungen über die Entwicklung der sog. 'Ganglienleiste' im Kopfe der Vögelembryonen," Morphologisches Jahrbuch, Bd. 20, 1893.

† "On the Inadequacy of the Cellular Theory of Development, and on the Early Development of Nerves, particularly of the Third Nerve, and of the Sympathetic in Elasmobranchii," Quarterly Journal of Microscopical Science, 1894, p. 87.

present." "In short, the development of nerves is not an outgrowth of cell processes from certain central cells, but is a differentiation of a substance which is already in position, and this differentiation seems to take place from the medullary walls outwards to the periphery, both in the anterior and posterior roots, and to precede, or to proceed *pari passu* with, the development of the other tissues." Notwithstanding the assertions of Sedgwick to the contrary, the axis-cylinders have been proved to be processes of ganglionic cells, and not only to arise as such in the embryo, but to exist as such in the adult. His statement (p. 94) that "The neuroblasts of His, and other authors, are nuclei lying in a substance which, after death caused by ordinary re-agents, has usually a fibrous structure," proves nothing, as long as nerve cells and their processes can be made out in perfectly fresh tissues, without the use of re-agents. Further, it seems scarcely expedient to remove the idea and word "cell" from anatomical description until Sedgwick can prove that animals which possess white blood corpuscles do not possess cells, in the general acceptation of the term, and therefore are not multicellular. The observations of physiologists and pathologists are also in favour of the cellular conception of the neuroblasts.

One important observation made by Sedgwick must here be noticed: writing of the third nerve, Sedgwick says that it, unlike the Gasserian ganglion, the mandibular branch of the fifth, the ramus profundus, and the ciliary (mesocephalic) ganglion does not "crystallise" out of the nerve crest, but "first makes its appearance as a forward projection from the ciliary (mesocephalic of Beard) ganglion. This forward projection extends itself, until it reaches the base of the midbrain." "The third nerve, therefore, presents this interesting and remarkable peculiarity in Scyllium and Acanthias: it grows or is differentiated from the ciliary ganglion to the floor of the mid-brain, and not in the opposite direction, as has hitherto been supposed."

With regard to this observation by Sedgwick, we have, I believe, a somewhat similar case in the development of the fourth nerve in Acanthias as described by Miss Platt. According to this author the fourth nerve is partly, at all events, developed as a cellular growth, or as Sedgwick would probably call it, "a cord of nuclei with rather dense pale substance," which grows from the ganglion of the fourth nerve towards the brain. According to Miss Platt, however, the fibrous fourth nerve, *i.e.* the axis cylinders, grow out from the brain itself, and not in the opposite direction. It seems then to me that in the case of the third nerve also, although a cord of nuclei may grow from the ganglion of the ophthalmicus profundus to the mid-brain in the forms studied by Sedgwick, that yet the fibres of the third may grow in the opposite direction through this nuclear cord which would then represent the "nervenfürendes" tissue of Goronowitsch. In mammals certainly the fibrous third nerve is developed from the brain outwards, and an examination of the specimens make it impossible to believe that the fibres in the early stage are not processes of cells in the brain.

Miss Platt has also traced the origin of the "cellular third nerve" as an outgrowth from the ciliary (or profundus ganglion). On the other hand, Goronowitsch says distinctly that the cellular cord which at first occupies the position of the future third nerve is developed independently of the nerve crest (ganglionleiste) from the mesenchyme, both in the chick and in bony fish. This cellular cord of Goronowitsch will afterwards be traversed by the axis cylinder processes of the true third nerve (p. 233).

It does not seem that Sedgwick has proved that the fibrous third nerve, *i.e.*, the functional third of the adult is developed in Elasmobranchs in a different manner from other motor nerves. The observations of Dohrn, on the other hand, show that the fibres of the nerve in Elasmobranchs are developed from the brain towards the periphery, and, therefore, in accordance with other motor nerves. The description of the fourth nerve given by Dohrn seems to throw light on the observation of Sedgwick. The cells of the ganglia of the fourth nerve are described by Dohrn as derived from the trigeminal complex, but yet the fibres of the nerve are formed from processes of the brain cells growing outwards.

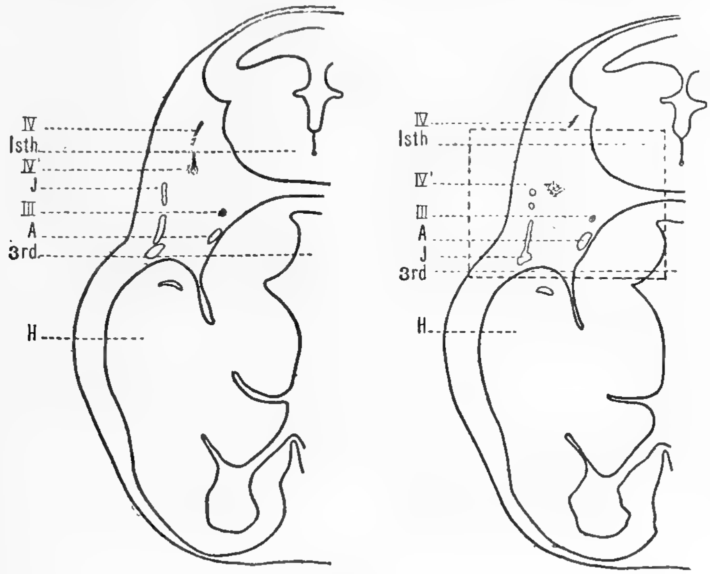

Figure 2.

Outlines of portions of two consecutive horizontal sections through the head of a rat embryo of 16 days. The sections lie near the region of origin of the fourth nerve. In the first, the fibrous fourth nerve is seen just as it enters the "ganglion," and in the second, the position of the ganglion is shown, cut at right angles to its long axis. A. artery. H. cerebral hemisphere. Isth. isthmus. J. tributaries of jugular vein. iii. third nerve. iv. fourth nerve. iv′. ganglion of fourth nerve. 3rd, third verticle.

The fibrous third nerve, like the fibrous fourth, will grow out from the brain as it has been described by so many authors. I may say that in the rat embryo the "ganglion" of the fourth nerve is a most conspicuous object, yet the fibrous fourth nerve is not developed from it towards the brain, but in the opposite direction, as in Elasmobranchs (Dohrn and Miss Platt). This "ganglion" of the fourth nerve is easily demonstrated in rat embryos after the thirteenth day. The nerve at its origin from the brain is fibrous, and also near its termination, where it is in relation to the frontal nerve. In the intermediate part of its course, on the other hand, the fourth nerve is represented by a relatively thick dense cellular cord. The cells of this cord have very distinct nuclei, and although among them there are some fibres, these latter are not nearly so conspicuous as those which form the fourth nerve above the "ganglion." The three accompanying drawings (figs. 2 and 3) illustrate the "ganglion" of the fourth nerve in the rat embryo. The "ganglion" appears first to have been described by Hoffmann* in reptiles; since then it has been described by Dohrn and Miss Platt† for Elasmobranchs. Dohrn‡ describes it as a cut off portion of the Trigeminal complex. In neither Elasmobranchs nor in the rat does it give rise to the fibrous fourth nerve, which grows out from the brain itself. I would venture to suggest that in this "ganglion" of the fourth nerve we have a similar structure to the cellular third nerve which Sedgwick describes as being developed from the anterior part (nasal) of the Gasserian ganglion towards the brain. In both cases we have a process of the Gasserian ganglion growing towards the brain, and in the case of the third nerve, just as in that of the fourth, all observers describe the *fibres* as growing out from the brain.

It must be noted that Dohrn§ contrasts sharply the ganglia of the third and fourth nerves, in Elasmobranchs, and considers the third nerve and its ganglion, to be developed in quite a different manner. Miss Platt's description agrees more closely with that of Sedgwick. On the other hand, it is just possible, that Sedgwick's third nerve may represent Ewart's|| ciliary ganglion, which is developed as a process of the ganglion of the ramus profundus.

When now we leave the question of the origin of the ciliary ganglion, and inquire what is the nature of the ganglion in the adult, we have at last certain information.

In 1881 Retzius, from microscopic examinations of the ciliary ganglion, came to the conclusion that it was sympathetic in nature. Onodi, Hoffmann, Beard, and a number of others, arrived at the same conclusion from observations on its

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* "Über du Metamerie des Nachhirns und Hinterhirns, und ihre Beziehung zu den segmentalen Kopfnerven bei Reptilienembryonen," Zool. Anzeiger, 1889, p. 337.

† Journal of Morphology, 1891, vol. v., p. 79.

‡ Mitt. a. d. Zool. Station zu Neapel, 1890, Bd. x., p. 11.

§ Mitt. a. d. Zool. Station zu Neapel, Bd. x., 1891, p. 11.

|| On the development of the ciliary or Motor Oculi Ganglion. Proceedings of the Royal Society, vol. 47, 1889, p. 287.

origin. Still the idea that the ciliary ganglion is in some sense the homologue of a spinal ganglion has supporters. Dohrn believes its origin to be different from the origin of true sympathetic ganglia. Speaking of the ciliary ganglion, he says, "letztere dürfen also keinesfalls mit den bisher ausschliesslich sympathische Ganglien genannten Bildungen in eine Kategorie geworfen werden."*

Von Gustaf Retzius† has, however, since shown that in the fœtus of the cat the ciliary ganglion contains "nur multipolar Nervenzellen von echte sympathischen Typus." These last observations of Retzius were made by Golgi's method of staining, and must be looked upon as conclusive in their results.

This conclusion, that the cells of the ciliary ganglion are of sympathetic type, agrees with the important observations of Langley and Anderson,‡ who, from a study of the effects of nicotine on the ciliary ganglion, came to the conclusion "that limiting attention to what has been actually proved about the ciliary ganglion there can be no hesitation in considering it as homologous with a sympathetic ganglion, although its nerve cells have no connection with the cervical sympathetic." Gaskell,§ who earlier still believed the ciliary to be a sympathetic

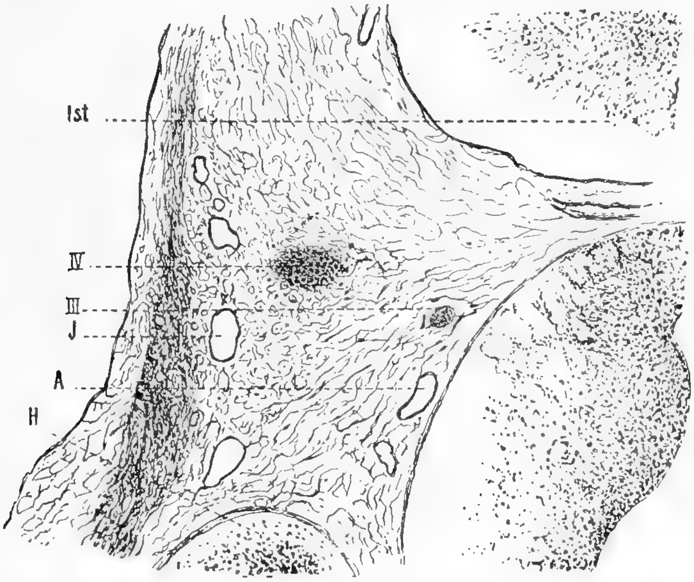

Figure 3.

Camera lucida drawing of a portion of section corresponding to the dotted outline in figure 2. The actual section from which the drawing was made lies 50 μ lower in the head than the one shown in figure 2. The lettering is the same as in figure 2, except that Ist. should read Isth.

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* Mittheilungen aus der Zool. Station zu Neapel, 1891, Bd. x., p. 32.

† Anatomischer Anzeiger, 1894, p. 633.

‡ "On the Action of Nicotine on the Cells of the Ciliary Ganglion, and on the Endings of the Third Nerve," Journal of Physiology, vol. xiii., 1892, p. 460.

§ "On the Relation between Structure, Function, Distribution, and Origin of the Cranial Nerves; together with a Theory of the Origin of the Nervous System of Vertebrata," Journal of Physiology, vol. x., 1889, p. 153.

ganglion (motor vagrant) in connection with certain fibres of the third nerve, fell into the error of considering its cells to possess structure similar to the cells of a spinal ganglion, and even compares the geniculate ganglion of the facial nerve to the ciliary ganglion. Both Gaskell, and Langley and Anderson admit, that they have only demonstrated, that the greater number of the cells of the ciliary ganglion are connected with fibres of the third nerve, while Gaskell describes a small group of cells in the ganglion connected with the fibres of the fifth nerve.

Superior Maxillary Division of the Fifth Nerve.

Embryo Br$_3$.—(4 weeks, 6·9 mm.). Figure 11, Plate II.

The superior maxiliary nerve takes origin from the anterior part of the Gasserian ganglion, and passes forwards and a little upwards, beneath the eyeball. The Gasserian ganglion above the origin of this nerve has a circular outline, in horizontal section, whereas, when the level of the superior maxillary nerve is reached, a section of the ganglion is egg-shaped, the pointed end of the egg corresponding to the place where the nerve arises. The length of the nerve is 0·4 mm.

No trace of Meckel's ganglion was found, unless the nuclei present among the fibres of the nerve near its origin represent the cells of a ganglion. This has been suggested by Professor His,* who, describing the cells present among the fibres of the superior and inferior maxillary nerves of this embryo, says:—"Dies das Hauptganglion überschreitenden Zellen sind als die Anlagen der kleinen Trigeminusganglien, des *G. rhinicum*, und des *G. oticum* anzusehen."

Embryo Ru.—(5th week, 9·1 mm.). Figure 12, Plate II.

The superior maxillary nerve, arising from the anterior part of the Gasserian ganglion, passes horizontally forwards beneath the eyeball. At first the fibres of the nerve are constricted into a compact bundle, but they spread out somewhat as they pass forward towards the face. A few bundles of fibres pass inwards towards the roof of the primitive mouth cavity. The length of the superior maxillary nerve is 0·8 mm.

At the level of the superior maxillary nerve, the third and sixth nerves end close to one another, the third nerve coming from above downwards, forwards, and a little outwards, and the sixth from below upwards, forwards, and a little

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* "Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim menschlichen Embryo," Abhandlungen d. Königl. Sächs Ges. d. Wissensch., 1888, Bd. iv., p. 372.

outwards. The termination of each is about 0·2 mm. from the inner side of the superior maxillary nerve near its origin, and just below the level of the eyeball.

The great superficial petrosal branch of the geniculate ganglion of the facial nerve ends about 0·4 mm. below the point of origin of the superior maxillary nerve. This branch of the geniculate ganglion, at this stage, does not communicate with the superior maxillary nerve. There is no Meckel's ganglion present, unless the nuclei present among the fibres of the nerve near its origin, represent the cells of a ganglion. These nuclei do not seem to be as numerous in this embryo as they are in BR_3., the representative of an earlier stage.

EMBRYO C.R.—(beginning of 6th week, 13·6 mm.). Figure 13, Plate II.

The superior maxillary nerve rises from the anterior surface of the Gasserian ganglion, a little nearer to its lower than to its upper end. The fibres of the nerve are, at first, tightly pressed together, as if constricted by a band drawn round them, but they soon spread out, especially in a horizontal direction. The inner fibres spread out most, some passing directly inwards, some inwards and forwards. Three or four fine branches communicate with Meckel's ganglion, which lies below, and to the inner side of the superior maxillary nerve.

Most of the fine nerves which run inwards from the superior maxillary are directed towards the roof of the primitive mouth cavity, behind the point where the choanæ communicate with it. These nerves, when viewed from above or below, form a loose layer of fine bundles, separated from each other by short intervals, apparently sometimes communicating with one another, and sometimes passing back into the main nerve trunk. The length of these inwardly directed nerves varies from 0·6 to 1·0 mm. The superior maxillary nerve passes forwards, until it is only about 0·5 mm. from the surface, here it divides into branches, the largest of which turn inwards towards the middle line. The course of the nerve lies some distance below, and to the inner side of the eyeball. Near its termination, and just before it divides into these terminal branches, the superior maxillary nerve turns a little upwards. The length of the nerve from its origin to the point of division is 1·4 mm. The terminal branches of the superior maxillary nerve turning inwards, give off many fine twigs, those of the lower branches, turning downwards, for the most part, and those of the upper ones, upwards. The twigs which pass upwards are the longest, and supply the surface of the face as high as the level of the equator of the eyeball. The lower branches of the superior maxillary nerve, below the level of the opening of the nose on the face, reach to within about 0·5 mm. of the middle line. Malar and temporal nerves come off the outer side of the main superior maxillary trunk. Both of these are very slender nerves, and the temporal passing outwards, and a little upwards, and backwards, behind the eyeball, comes nearer to the surface than the malar, which is directed downwards, outwards, and forwards, beneath the eyeball.

C.R.—Superior maxillary nerve from origin to final division = 1·4 mm.
Internal branches of superior maxillary . = 0·6—1·0 mm.
Malar nerve . . . . . = 0·4 mm.
Temporal nerve . . . . = 0·5 mm.
Terminal branches . . . . = 1·1 mm.

Meckel's ganglion is, I believe, represented by a collection of cells, placed to the inner side, and slightly below the level, of the superior maxillary nerve. A few branches connect the superior maxillary nerve with this aggregation of the cells. The outline of this ganglion is, in places not easily followed. Passing into the ganglion from below and behind, is the large Vidian nerve, some of the fibres of which break up into a number of fine bundles, among the cells of the ganglion. Some of the cells of the ganglion are continued downwards and backwards, along the outer side of the Vidian nerve, and become continuous with the cells of the otic ganglion. The ganglion is somewhat pear-shaped, the stalk of the pear corresponding to the place where the Vidian nerve joins the ganglion, and the swollen part to the large upper end of the ganglion, which is also turned outwards. The position and size of Meckel's ganglion in this embryo do not support the idea, that its cells are derived from the cells seen among the fibres of the superior maxillary nerve, in the former two stages. Many of the fibres of the Vidian nerve do not enter the ganglion of Meckel, but end in the tissue to its inner side.

Embryo F.M.—(7 weeks, 17·5 mm.). Figures 9 and 10, Plate I.

The superior maxillary nerve arises from the anterior aspect of the Gasserian ganglion, practically from its middle point. The direction of the nerve is horizontally forwards, bisecting the angle formed between the ophthalmic and inferior maxillary trunks. The foramen rotundum is already defined, and the nerve, while passing through it, has its fibres more closely packed together than they are seen to be, before the nerve enters the foramen, or after it issues from it. Immediately after the nerve leaves the foramen rotundum, it gives off two branches, which turn outwards, and two which turn inwards. The outer two branches represent the temporal and malar nerves, while the inner two go to Meckel's ganglion. The temporal and malar nerves (not shown in the figs.) at first lie close together, one behind the other, but as they pass outwards they diverge, the malar, which lies in front of the temporal, passing somewhat downwards. The temporal and malar nerves can each be traced a distance of 0·8 mm., when they end. Their terminations are 0·8 mm. apart. The temporal, as we have seen above (p. 27), communicates with the lachrymal branch of ophthalmic. The course of the two branches to Meckel's ganglion is obliquely inwards and forwards.

The superior maxillary nerve, having given off these branches, passes almost horizontally forwards, describing however, a very gentle curve, the convexity of which looks downwards. In this part of its course, the nerve gives off two fine branches, not more than 0·2 mm. in length, which pass downwards and forwards, but do not quite reach the roof of the mouth. These two branches which are not shown in the figures possibly represent the posterior and middle superior dental nerves of the adult. In front of these two nerves, a larger branch takes origin from the superior maxillary, which at first turns downwards and forwards, and then runs inwards, above the roof of the mouth, just behind its anterior border. This last nerve gives off fine branches which come near to the "Zahnleiste." This nerve probably represents the anterior superior dental of the adult. Soon after this last nerve is given off, the whole superior maxillary breaks up into a series of branches, which radiate from one another, some turning inwards, some inwards and upwards, and others inwards and downwards. A few fibres pass outwards and come very near to, if they do not actually communicate with, branches of the facial nerve.

F.M.—Length of superior maxillary to final breaking up = 2·0 mm.
Temporal branch . . . . . = 0·8 mm.
Malar branch . . . . . . = 0·8 mm.
Anterior superior dental . . . . = 0·9 mm.

Meckel's ganglion is placed to the inner side of the superior maxillary nerve, its upper border corresponding to the level of this nerve. The ganglion measures from side to side 0·4 mm., and from before, backwards, and downwards (its longest diameter) 0·6 mm. (fig. 10, Plate I.). The ganglion is placed close to the anterior and inner surface, of the block of cartilage, which separates the second and third divisions, of the fifth nerve, near their origins. From the outermost part of the ganglion, a curved horn-like projection passes round the upper surface of this cartilage, towards the Gasserian ganglion, from which, however, it is separated by a blood sinus. This horn-like process comes near to, and seems to communicate with, a somewhat similar process of the otic ganglion, which curves round the under and posterior aspect of the same cartilage.

The exact limits of the ganglion are not easily determined at all points, but it has a sharply defined lower and anterior surface, from which some fine branches come off, the probable representatives of the descending palatine branches of the adult. The fibres to form these descending palatine nerves can be traced through the ganglion from the two branches which are derived from the superior maxillary. These palatine nerves are three in number, the anterior one being the longest, and running downwards and forwards over the roof of the mouth, but not reaching as far as the "Zahnleiste." The two posterior branches are shorter, and more vertical in direction. The anterior branch is more than 1·0 mm. in length.

From Meckel's ganglion a branch also runs horizontally inwards, towards the mesial plane, the fibres of which seem to come chiefly from the Vidian nerve. This branch running inwards from the ganglion in this way probably represents the naso-palatine of the adult. Its length cannot be accurately determined. It is not shown in the figures.

The Vidian nerve, which joins the ganglion of Meckel in its posterior and inner part, can be traced to the geniculate ganglion of the facial. The direction of the Vidian, just before its termination in Meckel's ganglion is upwards, inwards, and a little forwards. The ganglion of the facial, from which the Vidian comes, lies quite free from the periotic capsule, and is not at this time surrounded by cartilage. Further, the geniculate ganglion lies very close to, if not in contact with the otic ganglion. The Vidian nerve is at first behind the otic ganglion, and then as it passes upwards, it inclines inwards, and a little forwards, crossing to the inner side of the otic ganglion. In its course the nerve lies at one time between the Eustachian tube and the periotic capsule, and while in this position it crosses the carotid artery on its outer and anterior aspect. As it crosses the carotid the Vidian receives a fine communication from a nerve which runs on the artery, and appears to rise chiefly from the trunk ganglion of the vagus nerve (see fig. 10, Plate I.). The Vidian also receives a very fine communicating branch from the nerve of Jacobson, which reaches it by running along the side of the carotid artery.

Embryo Mr.—(8 weeks).

The superior maxillary nerve, arising from the lower and anterior part of the Gasserian ganglion, runs forward and downwards through a distinct canal in the basis cranii. The course of the nerve is now forwards, beneath the eyeball and the eye muscles. To the inner side of the nerve near its origin, and on a slightly lower level, lies Meckel's ganglion. The nerve is connected with the ganglion by a well marked branch. The superior maxillary nerve ends near the surface of the face, below the eyeball, by breaking up into a number of branches, the longest of which turn inwards. The length of the nerve to its final breaking up is 2·2 mm. Just before the nerve divides into its terminal branches, it gives off a fine twig which passes downwards through the ossifying upper jaw, towards the "Zahnleiste." The length of this nerve was not determined, but it is at least 0·9 mm.

In Mr. the temporal and malar branches were not traced. Meckel's ganglion is very large and beautifully distinct, placed as it is, to the inner side of, and slightly below, the trunk of the superior maxillary near its origin. Continued into the ganglion is a large Vidian trunk, which, coming from the geniculate ganglion of the facial, crosses the otic ganglion on its upper and inner aspect. The Vidian in its course also comes close to the outer side of the carotid artery just as the latter is passing in between the cartilages of the basis cranii. A fine nerve running on the artery communicates with the Vidian in this position; also near this place a fine twig from the nerve of Jacobson joins the Vidian. Meckel's ganglion gives off a number of large branches, which pass down towards the roof of the mouth. The longest of these is 1·3 mm. in length.

From the upper and anterior part of Meckel's ganglion a fine nerve, with which are many nuclei, was traced forwards and upwards, and then outwards, to join, apparently, the branch of the third nerve which goes to the ciliary ganglion, and also partly the ciliary ganglion itself. This connecting nerve probably represents the branch described by Tiedemann and Arnold, and quoted by Schwalbe in his text-book.*

Meckel's ganglion in this embryo is relatively very large, having an antero-posterior diameter of 0·7 mm., and a transverse one of 0·8 mm.

The examination of the superior maxillary nerve in these five stages shows us that the nerve is at first unbranched, and further, that it is not connected with any ganglion except the Gasserian, from which it grows.

A distinct isolated ganglion of Meckel is not present in BR₃. (4 weeks), or RU. (5th week), nor indeed is one figured by Professor His† in K. O., an embryo larger than RU. Professor His, however, regards the nuclei present among the fibres of the maxillary nerve near its origin as the source of the cells of the ganglion of Meckel.

We have seen that these nuclei are present in large numbers at the end of the fourth week (BR₃.), while in the fifth week (RU.) they are not so plentiful. This observation, together with the fact that Meckel's ganglion, when it is first recognizable as such (C.R. beginning of 6th week), lies free from the nerve trunk, being only connected with it by fine branches, and is relatively of very large size, leads me to believe that the ganglion is not derived from the cells, seen among the nerve fibres of the superior maxillary, in the earlier stages. These cells may perhaps become a part of the ganglion, but they can scarcely form the whole of it. I believe, however, that it is more likely that the cells present at the end of the fourth week in BR₃. represent the "nervenführendes Gewebe" of

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* Schwalbe, "Lehrbuch der Neurologie," 1881, p. 821.

† "Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim menschlichen Embryo," Abhandlungen d. Königl. Sächs. Gesellschaft der Wissensch., 1888, Bd. xiv., fig. 3, plate II.

Goronowitsch, which disappear at a later stage, just as they do in the case of the ophthalmic nerve.

At the end of the fourth week—BR_3.—both superior and inferior maxillary nerves, possess more axis-cylinders than the ophthalmic nerve, and are thus further advanced in their development. Also at this time the superior and inferior maxillary divisions arise very close together, almost by a common stem, while both are at their origin widely separated from the ophthalmic. In the chick Remak, Marshall, His, Béraneck, Goronowitsch, and others, all describe the superior maxillary nerve, either as a later outgrowth from the Gasserian ganglion than the inferior maxillary nerve or as a branch of the latter nerve. A similar account has been given for the lizard by Béraneck, and for Petromyzon by Shipley. If we may judge from embryo BR_3., man differs from these lower forms in possessing a superior maxillary nerve which is formed early and independently of the inferior maxillary.* In the Guinea-pig, according to Chiarugi, the superior maxillary nerve is developed as a branch of the inferior maxillary.†

It is interesting to notice that in RU. (5th week) the Vidian nerve is already present as an outgrowth from the geniculate ganglion of the facial nerve, and ends at some distance from the superior maxillary nerve. The connection of the Vidian nerve with Meckel's ganglion, in older embryos and in the adult, must be a secondary one. This fact will be again referred to. I may say that in the rat the origin of the Vidian, or rather great superficial petrosal is easily proved to be from the geniculate ganglion of the facial. In this animal the nerve can be recognised as a fine twig, with many cells in its course, as early as the 13th day, stretching inwards from the geniculate ganglion towards the carotid artery (see figs. 4 and 5, p. 57).

In C.R. (beginning of 6th week) and F.M. (7th week), and also in another embryo of about the same age, viz. Wt., the cells of Meckel's ganglion are continuous with those of the otic by a narrow neck. This connecting neck of cells lies in part of its course inside the developing cranium to the inner side of the Gasserian ganglion. From its position this part of the cellular connection probably represents the aggregation of cells described for a human fœtus by Ewart,‡ and thought by him to represent the ganglion of the nasal nerve.

This close connection of the otic, with Meckel's ganglion, is probably to be associated with the intimate relationship, that exists in the embryo, between superior and inferior maxillary nerves.

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* Kupffer's recent account of the cranial nerves of Ammocoetes Planeri, shows that in this animal superior and inferior maxillary nerves arise at the same time from the Gasserian ganglion. "Studien zur vergleichenden Entwicklungsgeschichte des Kopfes der Kranioten," Heft. iii., München, 1895.

† Monitore Zool. Ital., December, 1894, p. 275.

‡ "On the Development of the Ciliary or Motor Oculi Ganglion." Proceedings of the Royal Society, 1889, vol. xlvii., p. 287.

Inferior Maxillary Division of the Fifth Nerve.

Br_3. (4 weeks 6·9 mm.). Figure 14, Plate II.

The inferior maxillary nerve takes origin from the lower end of the Gasserian ganglion, and passes forwards, downwards, and a little outwards. Near its termination, however, its course is almost vertically downwards. The inferior maxillary nerve in this embryo is a little longer than the superior maxillary, its length being 0·5 mm. nearly.

There is a bundle of fibres which lies between the superior and inferior maxillary trunks, but connected, apparently, with the inferior maxillary. These fibres are chiefly derived from the motor root of the trigeminal, and lying above the inferior maxillary nerve pass more outwards than the inferior maxillary itself. The length of these fibres is not more than 0·2 mm., and they probably represent the motor branch of inferior maxillary nerve, seen in older stages. They are not figured by Professor His in the Paper already referred to. Many nuclei are present among the fibres of the inferior maxillary nerve, but no aggregations of these to form either otic or submaxillary ganglia are present.

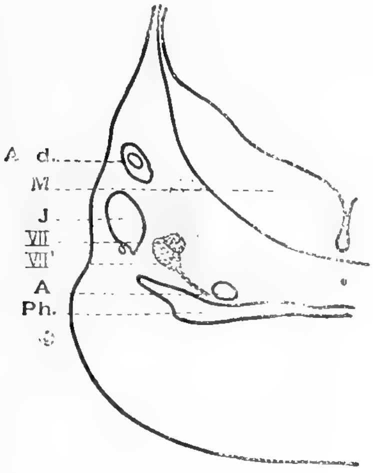

Figure 4.

Outline of portion of horizontal section through the head of a rat embryo of 14 days to show a very early condition of the great superficial petrosal nerve. A. carotid artery. Aud. internal ear. J. jugular vein. M. Medulla. Ph. cavity of pharynx and Eustachian tube. VII. facial nerve. VII′. geniculate ganglion of facial. The dotted outline indicates part of the ganglion of the VIII. nerve.

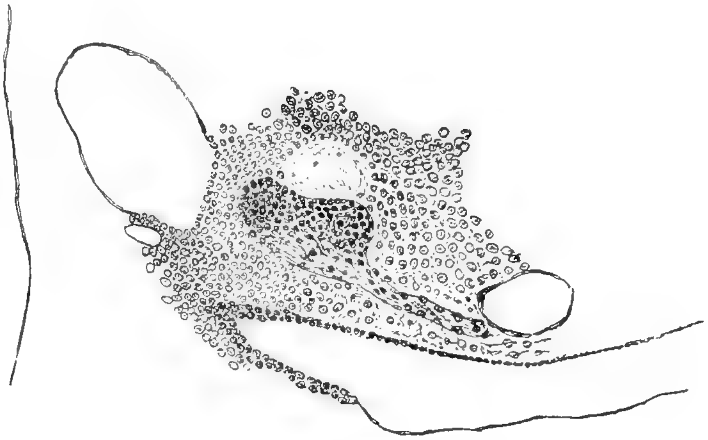

Figure 5.

Camera lucida drawing of a portion of the section, the outline of which is given in fig. 4. The great superficial petrosal nerve is seen growing out from the geniculate ganglion of the facial nerve towards the carotid artery. Among the fibres of the developing nerve a great number of nuclei are seen.

Embryo Ru. (5th week, 9·1 mm.). Figure 15, Plate II.

The inferior maxillary nerve arises from the lower part of the Gasserian ganglion, and into it can be traced the motor root of the trigeminal. The fibres of the motor root cross the sensory ones, and are present chiefly in the outer part of the inferior maxillary nerve. The nerve at its origin is relatively very thick, and is directed downwards and forwards, coming to lie on the outer aspect, of the upper end of Meckel's cartilage. The nerve now becomes much more slender, and turning somewhat inwards lies in front rather than on the outer side of Meckel's cartilage. Before the nerve thus changes its direction it gives off a very fine branch which passes behind, and to the inner side of the cartilage, and probably, as we shall see by a comparison with the next embryo, represents the communicating branch to the future lingual nerve.* Among the fibres of the inferior maxillary nerve near its origin are many nuclei, but no isolated otic ganglion was observed.

At a lower level than the small branch just noted, and like it, placed behind the inner side of Meckel's cartilage, is the terminal portion of the chorda tympani branch of the facial nerve. The tissue in which the chorda tympani, and perhaps also the small branch of the inferior maxillary nerve ends, has not quite the same appearance as the cellular tissue round about. Where these nerves end the nuclei close at hand are large, and a few scattered fibres are seen among them. This differentiated tissue may possibly represent the developing sub-maxillary ganglion. It is to be noted, that the chorda tympani nerve, is much larger than the other nerve, and further it is more closely connected with this differentiated tissue. This arrangement of these nerves was traced on both sides, and corresponded exactly. The main trunk of the inferior maxillary nerve, continued along the outer side of Meckel's cartilage, represents the inferior dental nerve. No distinct otic ganglion was found connected with the inferior maxillary nerve, in this embryo. The nerve of Jacobson is present in this embryo, as an outgrowth from the petrous ganglion of the glosso-pharyngeal, but is very short. This nerve passes vertically upwards, and ends a considerable distance below the level of the inferior maxillary nerve.

Ru.—Inferior maxillary nerve to origin of connecting branch = 0·6 mm.
Inferior maxillary nerve to termination of inferior dental = 1·2 mm.

Embryo C. R.—(beginning of 6th week, 13·6 mm.). Figures 16 & 17, Plate II.

The inferior maxillary nerve arises from the front and lower end of the Gasserian ganglion, and is the largest of the three branches of the fifth nerve.

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* Compare figures 15 and 16, Plate II.

The main trunk is very short, and passes forwards and a little downwards. Unlike the superior maxillary nerve its fibres are not constricted at its origin. The main trunk practically at once breaks up into a number of branches. The chief of these are—inferior dental with its mylo-hyoid branch, lingual, long buccal, and auriculo-temporal. The inferior dental is more a continuation of the direction of the main nerve trunk than the other branches are. In addition to these branches, which are easily identified, there are other twigs, which pass into the developing muscles. One such large branch, arising from the outer side of the nerve, and running almost horizontally forwards, ends in branches to the muscles, developing on the outer side of Meckel's cartilage. The other muscular twigs pass inwards from the main trunk near its origin, and are shorter although numerous. The long buccal nerve is the highest branch of the inferior maxillary, and passes forwards, describing a slight curve which is convex upwards. The nerve reaches as high as the outer limit of the mouth cleft, where it ends. The fibres to form the long buccal nerve come upwards from the inferior maxillary nerve, just in front of the point, where the chief part of the motor root, crosses outwards over the main nerve. Only the proximal and terminal parts of the long buccal are shown in the figure (fig. 16, Plate II.). The length of the long buccal is 0·8 mm.

The outer muscular branch, into which most of the fibres of the motor root can be traced, runs horizontally forwards, describing a curve slightly convex outwards. This nerve becomes constantly smaller and smaller, its fibres passing into the developing muscles. Its length is 0·5 mm.

The inner muscular branches pass directly inwards from the main trunk. They are short and stout, being about 0·25 mm. in length.

The auriculo-temporal branch (fig. 17, Plate II.) arises immediately beyond the nerves just described, and before the inferior maxillary divides into lingual and inferior dental. The nerve from its origin passes downwards and forwards, to the outer side of Meckel's cartilage, and ends in two branches, near the front of the external auditory depression. The length of the auriculo-temporal is 0·8 mm.

The inferior maxillary nerve, having given off the above branches, lies upon the upper surface of Meckel's cartilage just behind its inner turned up end. Here it divides into inferior dental and lingual nerves. The inferior dental passes forwards and inwards on the outer side of the high inner end of Meckel's cartilage, the lingual on the other hand passes forwards and inwards, internal to the cartilage. Just after the lingual and inferior dental nerves have separated from one another, they communicate by a very well marked connecting branch. The inferior dental nerve is the longest of the two terminal branches of the inferior maxillary, and passes forwards and inwards, at first, close to the outer surface of Meckel's cartilage, but then leaving the cartilage it turns more forwards, towards the surface of the face below the mouth cleft. The length of inferior dental is 1·6 mm.

The mylo-hyoid branch (fig. 17, Plate II.) is a long slender nerve, which takes origin from the inferior dental close to the origin of the latter. The nerve at first passes almost vertically downwards, on the outer side of Meckel's cartilage, and then, turning inwards beneath the cartilage, it reaches almost to the middle line. The length of mylo-hyoid nerve is 1·2 mm.

The lingual nerve arising at the same point as the inferior dental, is soon separated from the latter by the inner end of Meckel's cartilage. The course of the lingual is horizontally forwards, and inwards. Just behind the inner end of Meckel's cartilage the nerve enters the submaxillary ganglion; a few of the fibres passing through the ganglion can be traced a short distance into the tongue. Length of lingual nerve is 1·0 mm. The length of the inferior maxillary nerve to its division into lingual and inferior dental branches, is 0·4 mm.

The chorda tympani nerve (figs. 17 & 18, Plate II.) is a long, slender, but easily traced nerve, which passes almost vertically upwards from the facial, joining the lingual finally, by turning a little forwards. The nerve is placed close to the outer side of the developing Eustachian tube, and is separated from the external auditory pit by a considerable interval, in which are seen the developing cartilages of the middle ear.

The sub-maxillary ganglion, into which we have seen the fibres of the lingual nerve pass, is very well defined, and lies between Wharton's duct and the inner end of Meckel's cartilage.

The otic ganglion is placed to the inner side of the anterior part of the Gasserian ganglion. It is smaller than Meckel's ganglion, and its cells are more closely packed together. The Vidian nerve, on its way to Meckel's ganglion, passes behind, and to the inner side of, the otic ganglion. A fine branch from the petrous ganglion of the glosso-pharyngeal, can be traced into the lower and posterior part of the otic ganglion (fig. 18, Plate II.). This latter nerve, which represents the nerve of Jacobson, has an almost vertical course, and passes close to the point, where the Vidian nerve takes origin from the geniculate ganglion of the facial nerve. Part of the otic ganglion passes upwards and lies inside the developing cranium. At another point the otic and Meckel's ganglion are connected by a narrow neck of cells.

C. R.—Inferior dental . . = 1·6 mm.
Mylo-hyoid branch . = 1·2 mm.
Auriculo-temporal . . = 0·8 mm.
Lingual . . . = 1·0 mm.
Long buccal . . . = 0·8 mm.

EMBRYO F.M.—(7 weeks, 17·5 mm.). Figures 9 & 10, Plate I.

The inferior maxillary nerve rises from the lower part of the Gasserian ganglion, just in front of its lower end. The nerve passes downwards and forwards to the upper border of Meckel's cartilage, where it breaks up into its branches. The length of this part of the nerve is only 0·4 mm., and from it the nerve to the internal pterygoid muscle passes inwards.

The inferior dental nerve, as regards direction, is the continuation of the main trunk of the inferior maxillary. From its origin, at the upper border of Meckel's cartilage, the inferior dental nerve passes downwards and forwards, lying on Meckel's cartilage, close to its upper edge. The nerve is at first close to the cartilage, but as it passes inwards, it comes to lie some distance in front, and to the outer side of, the cartilage. In section, the ossifying mandible is seen to form a crescent of bone (figs. 19 and 20, Plate II.), in front and to the outer side of the nerve, so that the nerve is found to lie between Meckel's cartilage and the bone of the developing lower jaw. This bony plate, as it is traced in towards the middle line, divides into an upper and a lower segment. Through the gap left between these two parts of the bone the greater part of the inferior dental nerve escapes as the mental branch. The mental nerve at once divides into numerous twigs, which come towards the surface. Before the inferior dental passes through the bone it gives off at least two fine twigs, which pass up inside the bony plate to the "Zahnleiste." Further a very fine twig is carried on towards middle line, inside the bony plate, after the rest of the nerve has passed out. The length of the inferior dental is 1·6 mm.

The mylo-hyoid branch rises from the inferior dental close to the origin of the latter, and passing more downwards than the inferior dental, it crosses the outer surface of Meckel's cartilage, obliquely, from above, downwards, and forwards. Having reached the lower border of Meckel's cartilage, it is continued along it, towards the middle line. Before the nerve ends it lies a good deal lower than the cartilage. Its fibres end in the superficial part of the mylo-hyoid muscle. The length of the mylo-hyoid nerve is 1·6 mm.

The auriculo-temporal nerve, takes origin from the superficial surface, of the inferior maxillary division of the fifth nerve, and first turns directly outwards. The nerve soon turns downwards, crossing the meningeal artery, and then passes almost vertically downwards, over the outer aspect of Meckel's cartilage. The auriculo-temporal nerve crosses the cartilage nearer to its outer and upper end than the mylo-hyoid nerve does. The nerve, having crossed the cartilage, lies in front of the external auditory pit, where it breaks up into branches, which, turning towards the surface, come into relation with branches of the facial nerve.

A large trunk, into which can be traced, most of the fibres of the motor root of the trigeminal, also rises from the outer aspect of the inferior maxillary. This trunk turning outwards, downwards, and forwards, to the outer side of the internal maxillary artery, ends in the developing muscles.

The long buccal nerve is placed deeply, its general direction being forwards and a little downwards, towards the mouth cleft. It described, however, a curve which is convex upwards, and passes through developing muscle fibres, which lie at right angles to its direction, these muscle fibres probably represent the buccinator muscle. The nerve ends, after a course of 1·4 mm., on the outer side of the mouth cavity.

The lingual nerve comes from the deeper part of the inferior maxillary, and is placed close to the nerve to the internal pterygoid muscle. The lingual passes downwards and forwards, towards the middle line, behind and internal, to the upper border of Meckel's cartilage. Towards its termination, however, it is not as close to Meckel's cartilage, as it is in the first part of its course. The nerve, as it approaches the middle line, at first lies above the submaxillary gland, but soon the duct of this gland passes up behind it. The lingual nerve gives a distinct twig to the gland. The length of the lingual is 1·4 mm. The lingual nerve is joined near its origin by the chorda tympani, which passes upwards from the facial nerve, in close relation to the outer and upper end, of Meckel's cartilage. The chorda tympani is 1·6 mm. in length.

The submaxillary ganglion is a distinct aggregation of cells round the lingual nerve, where it lies above the submaxillary gland.

The otic ganglion lies to the inner side of the inferior maxillary nerve, but part of it is continued upwards, between the cartilages of the basis cranii, coming close to the Gasserian ganglion. This process of the otic ganglion seems to be continuous with a similar process of Meckel's ganglion. The Vidian nerve, on its way to Meckel's ganglion, is in very close relation to the otic ganglion; further, the cells of the otic and Meckel's ganglion become continuous along the outer side of the Vidian nerve.

F.M.—Inferior maxillary trunk to origin of lingual nerve = 0·4 mm.
Inferior dental nerve . . . . = 1·6 mm.
Mylo-hyoid branch . . . . = 1·6 mm.
Long buccal nerve . . . . = 1·4 mm.
Lingual nerve . . . . = 1·4 mm.
Chorda tympani . . . . = 1·6 mm.

In Embryo F.M., and also in another embryo of about the same age, namely, Wt., the fifth nerve is connected with the ninth and tenth cranial nerves, in the following manner *:—A fine twig, which represents the nerve of Jacobson, passes upwards from the petrous ganglion of the glosso-pharyngeal nerve into the interval between the Eustachian tube and the periotic capsule. This fine nerve lies at its origin in Wt., at least 0·3 mm., and in F.M., 0·25 mm. to the outer side of the carotid artery, which also ascends in this interval. As the artery and nerve ascend, the artery bends outwards towards the nerve. The nerve now divides into two branches, one of which runs on the outer side of the artery and joins the Vidian, as the latter nerve crosses the artery, while the other branch ends in the posterior and lower part of the otic ganglion, and therefore represents the small superficial petrosal nerve, of the adult. In addition to this nerve of Jacobson, which lies on the outer side of the carotid artery, there is a fine nerve present on the inner side of the carotid. This last nerve is continued along the side of the carotid, into the cranium, after it has given a communicating twig to the Vidian nerve. When traced in the opposite direction, the nerve on the inner side of the carotid, is found to spring chiefly from the trunk ganglion of the vagus nerve. In its course it crosses the petrous ganglion of the glosso-pharyngeal, and may receive some of its fibres from it. The position and connections of this last described nerve render it probable that it represents the "sympathethic," associated with the carotid, in the adult.

In Embryo Mr. (eighth week) the same branches of the inferior maxillary nerve are recognisable as in F. M., but the large motor branches, are given off to the individual muscles, and can now therefore be named. The connections of the smaller ganglia of the fifth, are much more easily traced than in the younger stages, also the ganglia themselves are very sharply defined. The otic ganglion is placed behind, and to the inner side, of the trunk of the inferior maxillary nerve. The ganglion is of large size, and from it a process can be traced up inside the cranium which comes close to the inner and under surface of the Gasserian ganglion.

This part of the otic ganglion, which lies inside the cranium, beneath the Gasserian ganglion, in C. R., F. M., and Mr. (and also in embryo Wt. about the same age as F. M.), probably represents the ganglionic mass, described by Ewart, in a five months embryo, as the ganglion of the ramus profundus branch of the ophthalmic nerve. In these embryos, it has however, no connection with the ophthalmic nerve.

In Mr., the connections of the ganglia of the fifth nerve with the petrous ganglion of the ninth, are practically similar to those described and figured for F. M. The nerve of Jacobson comes from the outer and upper part of the petrous ganglion of the glosso-pharyngeal, and passes upwards between the Eustachian

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* See fig. 10, Plate I.

tube, and the periotic capsule, lying a considerable distance to the outer side of the carotid artery. As the nerve passes upwards and forwards, it has connected with it several small aggregations of cells with large nuclei. The nerve divides into two branches, one of which passes inwards, and having communicated with the nerves round the carotid, joins the Vidian. The other branch of the nerve of Jacobson passes near the geniculate ganglion of the facial, and finally ends in the otic ganglion.

The carotid artery in this embryo is surrounded by a regular sheath of nerve fibres, which can for the most part be traced from the trunk ganglion of the tenth nerve, a few, however, also coming from the petrous ganglion of the glossopharyngeal.

The above observations on the inferior maxillary nerve show that at first the nerve is unbranched, and that the inferior dental nerve of the adult is to be looked on as the direct continuation of the first formed inferior maxillary division of the fifth nerve, just as the nasal nerve is the continuation of the first formed part of the ophthalmic division. I was at first inclined to conclude, that the short nerve in embryo Ru. (5th week), which takes origin from the inferior maxillary trunk, and passes behind Meckel's cartilage, represents the lingual nerve of the adult. Since, however, the point of origin of this nerve lies nearly 0·6 mm. from the place where the motor root crosses the sensory fibres of the inferior maxillary, I believe this small nerve cannot represent the lingual of the adult, but rather, the communication, which exists in the adult, between the inferior dental and lingual nerves. In embryo C.R., an older stage than Ru., the distance of the point of origin of the lingual nerve from the crossing point of the motor fibres, is only about 0·2 mm., but on the other hand the connecting branch between the inferior dental and lingual nerves corresponds very accurately in position to the small nerve seen in the Ru. Further, the lingual nerve when recognisable comes off the inferior maxillary at a much more acute angle than the small nerve in Ru. does. A reference to figures 15 and 16, Plate II., will, I think, make this point clear. The lingual nerve thus resembles the frontal in arising at a comparatively late period, and then growing so rapidly as to soon overtake in length the other earlier formed nerve. In the rat as in man I have found that the lingual nerve is formed late, and is for some time even shorter than the chorda tympani branch of the facial nerve.

From the start the greater part of the motor root of the fifth nerve crosses over the sensory fibres of the inferior maxillary division, and takes up a position in the outer part of the nerve. Writing on this point, Professor His* remarks that the

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* "Die morphologische Betrachtung der Kopfnerven," Archiv für Anatomie und Physiologie. Anat. Abth., 1887, p. 420.

connection of the motor root of the fifth nerve with the inferior maxillary division, is not at all similar to the connection which exists between the motor and sensory roots of a spinal nerve. In the case of the fifth cranial nerve the motor root simply crosses the sensory fibres, and at once passes into the muscles of mastication; an exchange of fibres between the motor and sensory parts takes place only to a very limited extent—" nur zwei Zweige erfahren einen wirklichen Austausch der Bahnen, der mit dem N. mandibularis gehende N. mylohyoideus und der in Begleitung der Muskelnerven gehende N. buccinatorius." Professor His notes that there is thus no *à priori* reason why the motor root of the fifth nerve should not be counted a distinct cranial nerve as has been suggested by Faesebeck.

All the important branches of the inferior maxillary nerve are represented in the embryo in the beginning of the sixth week (C.R.), just as we have found all the branches of the ophthalmic division are.

The two accessory ganglia of the inferior maxillary nerve (otic and submaxillary) appear about the same time, the submaxillary possibly a little earlier than the otic (see page 58), and no proof was found that their cells are derived directly from the cells of the Gasserian ganglion. The connections of these ganglia with the inferior maxillary nerve, can in no sense be compared to the connection which exists between a spinal ganglion and its posterior nerve root, for the accessory ganglia of the inferior maxillary nerve do not appear until after the branches with which they are connected, have been formed. These embryological observations are in accordance with the results of Von Gustaf Retzius,* who finds, that the cells of these ganglia, just as those of the ciliary and the ganglion of Meckel, possess the characters of typical sympathetic nerve cells.

The development of the connections of the trigeminal with the seventh and ninth nerves is of great interest. In the above description it will be seen that in RU. (5th week) the chorda typani nerve does not join the lingual (page 58 and fig. 15, Plate II.), but that it is connected only with the seventh nerve. The chorda tympani is thus developed from, and is a branch of, the seventh nerve. Also in this embryo the Vidian nerve (page 51) does not yet communicate with the ganglion of Meckel, or superior maxillary nerve; thus the Vidian, or great superficial petrosal, must be looked on as a branch of the geniculate ganglion of the facial, with which it is seen to be in connection. Professor His has described and figured the chorda tympani as arising from the facial in embryo K.O., which is a little more than 1 mm. longer than RU. Further, I may state, that in the rat embryo, there is no doubt, that in the first instance both Vidian and chorda tympani have no other connections except with the seventh nerve, as in man. The nerve of Jacobson in RU. (5th week) is seen to be an outgrowth of the petrous ganglion of the glosso-pharyngeal nerve, and is not yet connected with the trigeminal

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* " Ueber das Ganglion Ciliare," Anatomischer Anzeiger, July, 1894, p. 633.

(see page 58). This agrees exactly with what may be observed in the rat, in which animal also, the nerve of Jacobson grows out from the petrous ganglion of the glosso-pharyngeal nerve. The fact that these connecting nerves are not branches of the trigeminal, but of the facial and glosso-pharyngeal, renders it improbable that through them taste impressions are transmitted to the fifth nerve, and so to the brain.

From analogy with what is known for other nerves we would expect that impulses, of whatever kind they may be, transmitted by these connecting nerves, would pass to the brain by way of the facial and glosso-pharyngeal nerves. It is true that Penzo* considers that he has proved, from dissections of the nerves in the adult, that the chorda tympani and the great superficial petrosal nerves contain fibres derived from the fifth nerve. If this is so, these fibres must grow out from the fifth nerve into the course of the Vidian and chorda tympani at a later period than the stage represented by Ru. (5th week). Whether fibres actually do grow back from the fifth nerve, into the course of the seventh and ninth nerves, would be very difficult to determine, and if such fibres exist and convey taste impulses into the path of the trigeminal, their late formation is a remarkable fact. On the other hand, since the facial and glosso-pharyngeal nerves are, at all events, in part developed as sensory nerves, and since the ganglia present in connection with them in the adult, possess the characters of ganglia on posterior nerve roots, there is no reason for denying them sensory branches.

Embryologically, the nerve supply of the organs of taste, appears to be derived from the facial and glosso-pharyngeal nerves alone, since the lingual admittedly in itself contains no taste fibres.

In the fact that the Vidian and the nerve of Jacobson, in addition to the chorda tympani, are not branches of the fifth nerve, we have an example of the tendency exhibited by the posterior cranial nerves, to turn upwards and trespass beyond their proper areas of distribution, as has been illustrated by Professor His.†

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* "Ueber das Ganglion geniculi und die mit demselben zussamenhängenden Nerven," Anatomischer Anzeiger, 1893, p. 738.

† "Die Morphologische Betrachtung der Kopfnerven," Archiv für Anat. und Phys. Anat. Abth., 1887, p. 449.

General appearance of the Gasserian Ganglion and chief branches of the Fifth Nerve.

In Embryo F. M. (see figs. 9 and 10, Plate II.), the Gasserian ganglion is egg-shaped, the pointed end of the egg corresponding to the upper end of the ganglion, just behind where the ophthalmic nerve takes origin. The long axis of the ganglion runs from above, downwards, and a little backwards and outwards. Its longest diameter is 1·3 mm., its transverse diameter 0·8 mm. The fibres of the motor root, which rise from the pons in front of, and to the inner side of, the sensory fibres, form a distinct flat band crossing the ganglion obliquely, downwards and forwards, on its inner side, near its lower broad end. This band of fibres is continued into the inferior maxillary nerve, and forms a distinct groove on the ganglion, as it crosses it, just as if a string had been tightly drawn across it. The cells of the ganglion are continued further towards the pons, on the upper and anterior part of the motor root than behind, and here form a deeply staining conical mass.

The anterior surface of the ganglion possesses three little conical projections, each of which corresponds to the origin of one of the divisions of the fifth nerve. These little conical elevations lie one above the other, but not directly so, as the first or upper is a little internal to the middle, and the middle a little internal to the lowest; further, the middle is behind the upper, and the lower behind the middle. The divisions of the fifth nerve, taking origin at these elevations, radiate from one another in such a way that the ophthalmic and inferior maxillary nerves enclose between their lines of direction an angle of 90°, while the direction of the superior maxillary nerve bisects this angle. It is interesting to note that for the adult, Schwalbe* has described the courses of the first and third divisions of the fifth, as inclined to one another at an angle of 90°, so that probably the embryonic orientation of the main trunks of the fifth nerve, persists in the adult.

The appearance of the Gasserian ganglion, and the origin of the divisions of the fifth nerve in Ob. and Wt. were found to correspond accurately with what has just been described for F. M., Ob., and Wt., being embryos a little younger, and a little older than F. M.

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* "Lehrbuch der Neurologie," 1881, p. 825.

Summary.

1. Before the ophthalmic nerve is present in the embryo, a cellular cord stretches upwards and forwards from the Gasserian ganglion, and occupies the place of the future nerve. This is easily demonstrated in the rat, and a similar condition appears to prevail in the human embryo.

2. Axis-cylinder processes grow out from the cells of the Gasserian ganglion into this cellular cord, and in this manner the ophthalmic nerve is formed.

3. The axis-cylinder processes increase in number, while the cells of the original cord become fewer, and at the same time become disposed around the developing nerve.

4. The first formed ophthalmic trunk corresponds to the nasal nerve of the adult.

5. The frontal nerve is formed later, and its proximal part in man is united in a common trunk with the proximal part of the nasal nerve. In the rat, however, the nerves in the first instance, take separate origin from the Gasserian ganglion.

6. In mammals no outlying part of the Gasserian ganglion is present as a ganglion either for the ophthalmic or nasal nerve, in the sense of a ganglion of a posterior nerve root.

7. A single undivided Gasserian ganglion gives rise to all three divisions of the fifth nerve.

8. In the beginning of the sixth week all the important branches of the ophthalmic nerve of the adult are represented in the embryo.

9. The fourth and frontal nerves are from an early period closely connected.

10. The ciliary ganglion is first recognizable as a distinct cellular mass at the beginning of the sixth week.

11. The ciliary ganglion appears, in the first instance, to be more closely connected with the frontal and fourth nerves, than with the nasal and third nerves.

12. Later this ganglion shifts its position, and in the eighth week it has established the connections, and assumed the situation, that obtains in the adult.

13. The ciliary ganglion can in no sense be the homologue of a spinal ganglion.

14. The superior maxillary nerve appears as an independant branch of the Gasserian ganglion, in the embryo of four weeks.

15. Soon the fibres of the superior maxillary nerve spread out horizontally, and are not collected so compactly into a single bundle as are the fibres of the other two divisions of the fifth nerve.

16. All the important branches of the superior maxillary are present in an embryo of seven weeks.

17. Meckel's ganglion is present as a distinct cellular mass at the beginning of the sixth week.

18. Meckel's ganglion, in the embryo, is closely connected with the otic ganglion.

19. The inferior maxillary nerve is at first unbranched.

20. The first formed part of the inferior maxillary represents the inferior dental of the adult.

21. The lingual nerve is formed later, and is not recognisable in the fifth week.

22. Meckel's cartilage presents a close relation to the branches of the inferior maxillary nerve, and seems to determine the directions which they take.

23. All the important branches of the inferior maxillary nerve are represented in the embryo at the beginning of the sixth week.

24. At the beginning of the sixth week the otic and submaxillary ganglion are present.

25. The chorda tympani, the Vidian, and the nerve of Jacobson, are not branches of the fifth nerve, inasmuch as they are not developed from it.

26. The chorda tympani and Vidian nerves are branches of the facial, being developmentally derived from this nerve. The nerve of Jacobson is, in like manner, a branch of the glosso-pharyngeal.

27. The origin of these nerves in man is precisely similar to what is observed in the rat.

28. There is no direct evidence to prove, that the cells of the accessory ganglia of the fifth nerve, are derived directly from the cells of the Gasserian ganglion.

29. The sympathetic, associated with the carotid artery in the adult, is represented in the embryo by fibres chiefly derived from the trunk ganglion of the Vagus nerve.

I have to express my indebtedness to Professor J. M. Purser for a large series of beautifully preserved rat embryos of different ages, and also to Professor D. J. Cunningham for much help and valuable criticism.

PLATES I. AND II.

LETTERING COMMON TO ALL FIGURES.

A.,	Internal carotid artery and its branches.
a.t.,	Auriculo-temporal nerve.
c.g.,	Ciliary ganglion.
c.t.,	Chorda tympani nerve.
E.,	Eyeball.
E.e.,	External ear.
E.t.,	Eustachian tube.
f.,	Frontal nerve.
G.g.,	Gasserian ganglion.
I.e.,	Internal ear.
i.d.,	Inferior dental nerve.
Inf.,	Infundibulum.
i.t.,	Infratrochlear nerve.
J.,	Jugular vein or its tributaries.
Jac.	Nerve of Jacobson.
l.,	Lingual nerve.
lach.,	Lachrymal nerve.
l.b.,	Long buccal nerve.
M.,	Mouth.
M.c.,	Meckel's cartilage.
Med.,	Medulla.
M.g.,	Meckel's ganglion.
m.h.,	Mylo-hyoid nerve.
M.o.,	Ossifying mandible.
m.r.,	Motor root of fifth nerve.
n.,	Nasal nerve.
N.f.,	Nasal fossa.
o.g.,	Otic ganglion.
O.p.,	Olfactory plate.
P.,	Pons.
Ph.,	Pharynx.
Pit.,	Pituitary body.
R.,	Roof of primitive mouth.
s.g.,	Submaxillary ganglion.
s.m.,	Superior maxillary nerve.
s.o.,	Supraorbital nerve.
S.p.,	Styloid process.
s.t.,	Supratrochlear nerve.
t.m.,	Temporo-malar nerve.
T.f.,	"Zahnleiste."
Vid.,	Vidian, or great superficial petrosal nerve.
W.d.,	Wharton's duct.
I., II., III., IV., V., VI., VII., VIII., IX., X.,	Cranial nerves.

Nerves,	Green.
Blood-vessels,	Red.
Cartilage,	Blue.
Cut surface of brain or eyeball,	Oblique shading.

EXPLANATION OF THE FIGURES ON PLATES I. AND II.

Figure

1. Outline of embryo Br_3. (4 years old), × about 3 diameters. The outline is reduced from a drawing of Professor His's. The longest diameter of this embryo is 6·9 mm.

2. Outline of embryo Ru. (5th week), × about 3 diameters, reduced from a drawing by Professor His. The length of this embryo from the cervical to the caudal bend is 9·1 mm.

3. Outline of embryo C.R. (beginning of 6th week), × about 3 diameters, reduced from a drawing by Professor His. This embryo measures 13·6 mm. from the cervical to the caudal bend.

4. Outline of embryo F.M. (seven weeks), × 3 about diameters, reduced from a drawing by Professor His. This embryo measures from the cervical to the caudal bend 17·5 mm.

5–18. Are drawings of reconstructions from sections through the heads of these embryos. Each drawing may be taken to represent a magnified view of a very thick section.

5. Drawing of a reconstruction, to show the course and position of the ophthalmic nerve in embryo Br_3. This drawing corresponds to a section cut horizontally through the head, 0·32 mm. in thickness, and × 25 diameters, *seen from below.* The ophthalmic nerve is shown cut across at the point where it leaves the Gasserian ganglion. The course of the nerve is upwards and slightly inwards. The relationship of the third and ophthalmic nerves is also shown.

6. Drawing of a reconstruction to illustrate the course of the ophthalmic nerve in embryo Ru. This drawing corresponds to a portion of a horizontal section through the head, 0·4 mm. in thickness, × 25 diameters, *seen from above.* Deep down in the reconstruction the top of the Gasserian ganglion is seen ; and the ophthalmic nerve ascending from it is observed to divide into frontal and nasal branches. The frontal branch is short and ascends nearly vertically, while the nasal branch, which is much longer, passes forwards over the optic stalk, towards the upper part of the nasal fossa. The terminal parts of the third and fourth nerves, are also seen, passing downwards and forwards.

7. Drawing of a reconstruction to illustrate the origin of the ophthalmic nerve in embryo C.R. The drawing corresponds to part of a horizontal section through the head, 0·2 mm. in thickness, × 25 diameters, *seen from above.* The nasal and frontal nerves are seen cut across, the former just at the point where it crosses the optic stalk. The lachrymal nerve is shown passing outwards behind the eyeball. The relationship of the terminal portion of the third nerve, to the Gasserian ganglion and optic stalk, is indicated. The extreme summit of the Gasserian ganglion has been cut off at the upper surface of this thick section. In the anterior part of the drawing the nasal fossa is seen opening on to the face.

8. Drawing of a reconstruction to illustrate the terminal branches of the ophthalmic nerve in embryo C.R. This drawing corresponds to a portion of a horizontal section through the head, 0·7 mm. in thickness, × 25 diameters, *seen from above.* The frontal nerve is seen turning outwards over the eyeball, and dividing into supraorbital and supratrochlear branches. The nasal nerve on the other hand passes forwards and inwards towards the roof of the nasal fossa. The nasal gives off an infratrochlear branch. In connection with the undivided frontal is an oval mass of cells which probably represents the ciliary ganglion of the adult. The fourth nerve is seen to communicate with the frontal, and then to end in this oval mass. A small portion of the third nerve is seen in the upper part of the figure. The thick section represented by this drawing lies in the head immediately above the one represented by fig 7.

Figure

9. Drawing of a reconstruction to illustrate the chief branches of the fifth cranial nerve in F.M. This drawing corresponds to a sagittal section through the head, 1·6 mm. in thickness, × 12·5 diameters, *seen from the outside.* The large Gasserian ganglion is seen lying in front of the pons and behind the eyeball. The nasal and frontal branches of the ophthalmic are seen in their proximal parts, but the lachrymal nerve is not indicated. Only the main trunk and terminal branches of the superior maxillary nerve are shown. The different branches of the inferior maxillary are seen grouped round Meckel's cartilage. Passing along the outer side of the cartilage, near its upper border, is the inferior dental nerve, the mylo-hyoid branch of which passes downwards on the outer side of the cartilage. The auriculo-temporal nerve also passes downwards on the outer side of the cartilage, but as it does so, it lies a considerable distance behind the mylo-hyoid nerve. The lingual nerve is seen in only a very short part of its course, since it almost immediately passes downwards and forwards to the inner side of Meckel's cartilage, which hides it from view. The long buccal lies at a higher level than the other branches of the inferior maxillary nerve. The long slender chorda tympani is seen passing upwards from the facial nerve, to join the lingual, just as the latter disappears on the inner side of Meckel's cartilage.

10. Drawing of a reconstruction to illustrate the chief branches of the fifth nerve, in embryo F.M., and also the positions of the smaller ganglia (except the ciliary) connected with the fifth nerve. This drawing corresponds to a sagital section through the head, 0·6 mm. in thickness, × 12·5 diameters, *seen from the inner side.* The motor root of the fifth nerve is seen passing downwards and forwards, across the posterior part of the inner aspect of the Gasserian ganglion, to join the inferior maxillary nerve. The proximal parts of the nasal and frontal nerves are seen passing upwards and forwards, the frontal lying at a higher level than the nasal. Only the chief branches of the superior and inferior maxillary nerves are indicated. Meckel's ganglion lies to the inner side of, and at a slightly lower level than, the superior maxillary nerve. Reaching the posterior part of the ganglion we see the Vidian nerve, which, in its course, crosses the outer side of the carotid artery, and lies close to the inner side of the otic ganglion. The otic ganglion is placed to the inner side of the inferior maxillary nerve, and is joined below by a slender branch from the petrous ganglion of the glosso-pharyngeal. This connecting nerve is seen passing up in the same interval as the carotid artery, between the Eustachian tube and the periotic capsule. The relations of the lingual, inferior dental, and mylo-hyoid nerves to Meckel's cartilage are brought out, but only a very small portion of the submaxillary ganglion is indicated. The ganglia of the glosso-pharyngeal and pneumogastric nerves are shown, as is also a small portion of the ganglion of the eighth nerve in connection with the internal ear.

11. Drawing of a reconstruction illustrating the Gasserian ganglia and the superior maxillary nerves in embryo Br_3. This drawing corresponds to a horizontal section, 0·28 mm. in thickness, × 25 diameters, *seen from above.* The pons is seen cut transversely, and taking origin from it, on either side, we have the sensory roots of the fifth nerve. The large Gasserian ganglia, at the level of the superior maxillary nerves, are oval in horizontal section. The superior maxillary nerves are stout, and run nearly horizontally forwards. The roof of the primitive mouth-cavity is seen deep down in the section, and passing down towards it we have the infundibulum, while coming up from it is the pituitary invagination.

12. Drawing of a reconstruction to illustrate the superior maxillary nerve in embryo Ru. This drawing corresponds to a portion of a horizontal section through the head, 0·25 mm. in thickness, × 25 diameters, *seen from above.* The large Gasserian ganglion and the roots of the fifth nerve are seen in section. The fibres of the motor root are cut transversely. From the Gasserian ganglion the superior maxillary nerve passes horizontally forwards, its fibres spreading out as it comes forwards. The terminal parts of the sixth and third nerves are shown. The dotted line indicates the outline of the roof of the primitive mouth-cavity.

Figure

13. Drawing of a reconstruction to illustrate the superior maxillary nerve in embryo CR. This drawing corresponds to a portion of a horizontal section through the head, 0·6 mm. in thickness, × 25 diameters, *seen from above.* The loose arrangement of the bundles of fibres of the superior maxillary nerve, at this stage, is shown. Meckel's ganglion, which is placed to the inner side of the superior maxillary nerve, is only very slightly connected in this nerve. Meckel's ganglion has a process which passes in between the cartilages of the basis cranii towards the Gasserian ganglion. The Vidian nerve is connected with the lower part of Meckel's ganglion, some of its fibres ending in it, while the rest of the nerve is continued upwards and forwards towards the roof of the primitive mouth-cavity. A portion of the sixth nerve is seen crossing the carotid artery. The roof of the primitive mouth-cavity with the choanæ is shown

14. Drawing of a reconstruction illustrating the inferior maxillary nerve in embryo Br_3. This drawing corresponds to a horizontal section through the head, 0·28 mm. in thickness, × 25 diameters, *seen from above.* The nerve present in this stage is found to represent the inferior dental nerve of the adult. The Gasserian ganglion, with its motor and sensory roots, is seen in section. The opening of the primitive mouth on to the face is seen.

15. Drawing of a reconstruction to illustrate the inferior maxillary nerve in embryo Ru. The drawing corresponds to a portion of a horizontal section through the head, 0·6 mm. in thickness, × 25 diameters, *seen from above.* The lowest part of the Gasserian ganglion lies in this section, and taking origin from it are the sensory fibres of the inferior maxillary nerve. The motor root is seen crossing the main nerve from within outwards. The direction of the inferior maxillary nerve is forwards and downwards, but finally it turns somewhat inwards, in front of Meckel's cartilage. The whole nerve (omitting the motor fibres) present in this stage, probably represents the inferior dental nerve of the adult. The small branch given off towards the back of Meckel's cartilage appears to represent the communication found in the adult between the inferior dental and lingual nerves. The facial nerve and its geniculate ganglion are seen lying deeply in the section; the Eustachian tube passing outwards, between the facial and the inferior maxillary nerve. From the facial nerve the chorda tympani branch passes upwards, and ends near the small branch of inferior maxillary, behind Meckel's cartilage. The first part of the great superficial petrosal nerve is seen taking origin from the geniculate ganglion, and turning inwards towards the carotid artery; the nerve then has a more vertical course, lying not far from the carotid artery.

16. Drawing of a reconstruction illustrating part of the inferior maxillary nerve in embryo CR. The drawing corresponds to portion of a horizontal section through the head, 0·3 mm. in thickness, × 25 diameters, *seen from above.* The inferior maxillary nerve is seen taking origin from the Gasserian ganglion, and the crossing of the sensory fibres by the motor root is also shown. Immediately in front of this crossing the long buccal is seen to take origin. Only the proximal and terminal parts of this nerve are shown, as the intermediate part lies above the level of the section. The terminal part comes forwards towards the angle of the primitive mouth. The inferior maxillary nerve divides after a very short course into lingual and inferior dental branches; these are however connected further on by a very distinct communicating branch. These two nerves are finally separated by the inner end of Meckel's cartilage. The lingual nerve enters the submaxillary ganglion. The otic ganglion lies to the inner side of the motor root of the fifth nerve. Passing upwards and forwards on the inner side of the otic ganglion we have the great superficial (Vidian) branch from the facial. The roots and ganglion of the seventh nerve, which should lie in the upper part of this section, partly under cover of the Gasserian ganglion, have been omitted.

Figure

17. Drawing of a reconstruction to show some of the branches of the inferior maxillary nerve in embryo CR. This drawing corresponds to a horizontal section, 0·4 mm. in thickness, × 25 diamaters, *seen from above.* The auriculo-temporal nerve is seen passing downwards on the outer side of Meckel's cartilage. The mylo-hyoid also passes downwards on the outer side of the cartilage, but it then turns forwards and inwards beneath the cartilage. The lingual nerve lies along the inner and upper border of the cartilage, and enters finally the submaxillary ganglion, which lies in front of Wharton's duct. A small part of the chorda tympani branch of the facial is seen just before it joins the lingual. The chorda tympani ascends close to the inner side of Meckel's cartilage. A portion of the facial nerve itself is seen passing downwards and forwards, and portions of the ganglia of the eighth nerve are seen in relation to the internal ear. The nerve of Jacobson is not indicated; it would lie between the internal ear and the wall of the pharynx. The section represented by this drawing lies in the head, just below that represented by fig. 16.

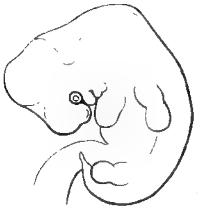
18. Drawing of a reconstruction to illustrate the origin of the chorda tympani branch of facial, and also that of the nerve of Jacobson in embryo CR. This drawing corresponds to a horizontal section, 0·3 mm. in thickness, × 25 diameters, *seen from above.* The chorda tympani is seen coming off the facial at an acute angle, and passing upwards to the outer side of the Eustachian tube. The nerve of Jacobson takes origin from the petrous ganglion of the glosso-pharyngeal, and passes upwards almost vertically. The section represented by this drawing lies in the head, a little distance below that represented by fig. 17.

19–20. Outlines of parts of two vertical antero-posterior sections of embryo F.M., × 25 diameters, to show the relationship between Meckel's cartilage, the developing mandible, the lingual nerve, the inferior dental nerve, and the mylo-hyoid nerve. In the section represented by fig. 19, which is the further from the middle line, the inferior dental nerve is placed between Meckel's cartilage and the developing mandible, the mylo-hyoid nerve lies below Meckel's cartilage, and the lingual nerve is above its upper border. In fig. 20, which represents a section in the region of the mental foramen of the adult, we see the developing mandible composed of two parts separated by an interval, which gives passage to the mental branch of inferior dental. In fig. 20 the lingual nerve lies a considerable distance above and behind Meckel's cartilage, and the mylo-hyoid nerve some distance below.

Plate I


1

Br_3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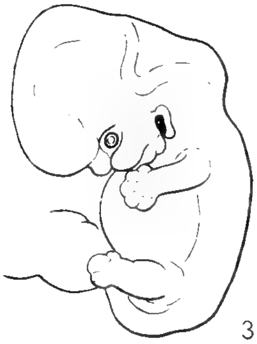
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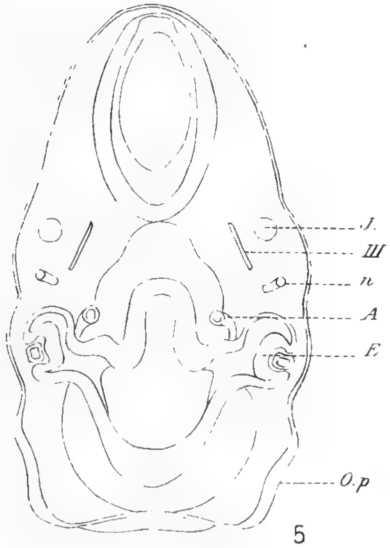

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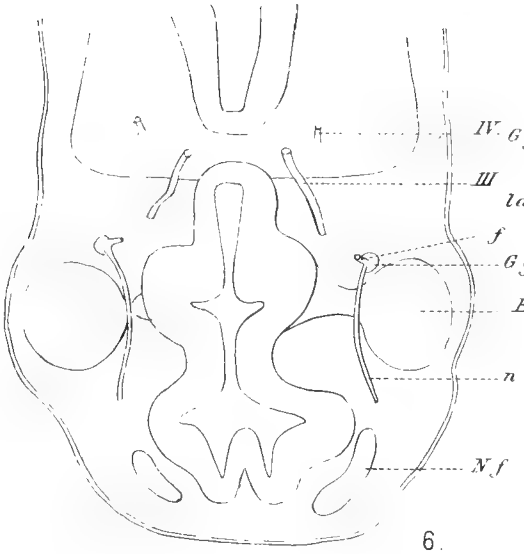

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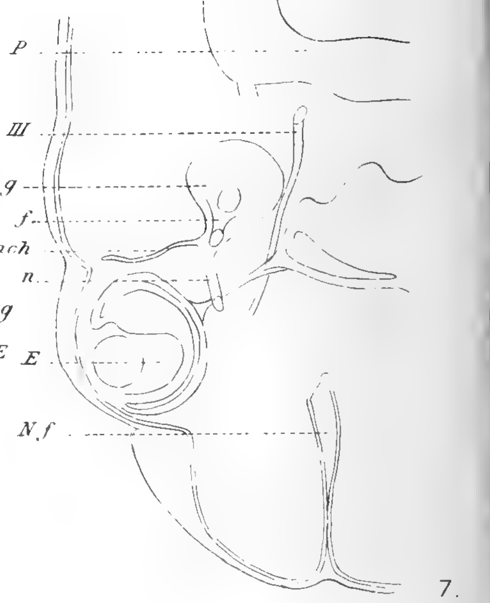

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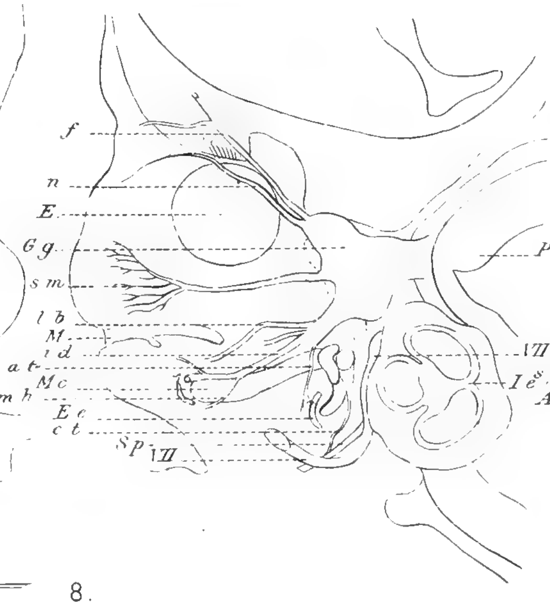

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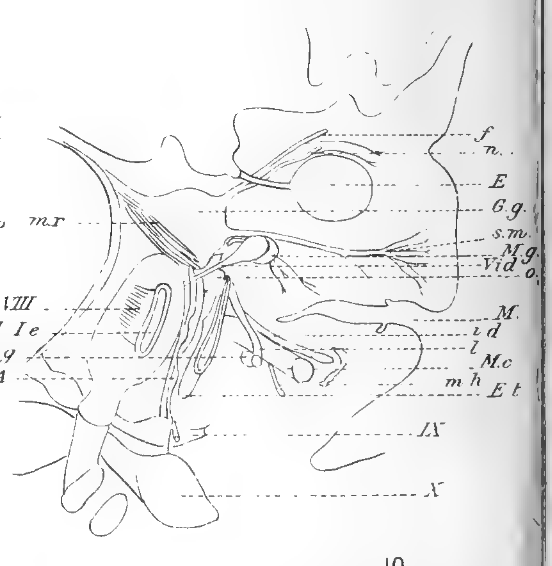

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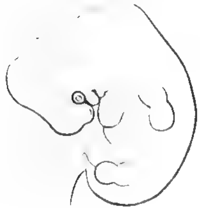
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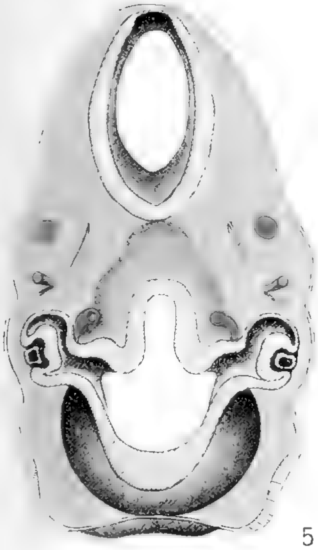
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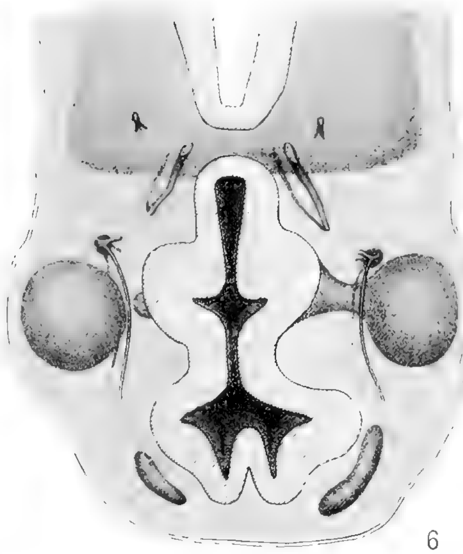
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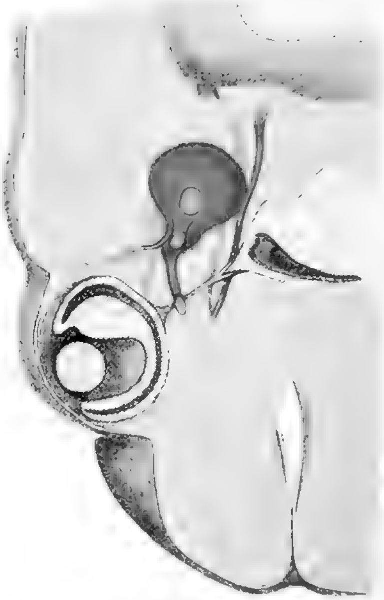
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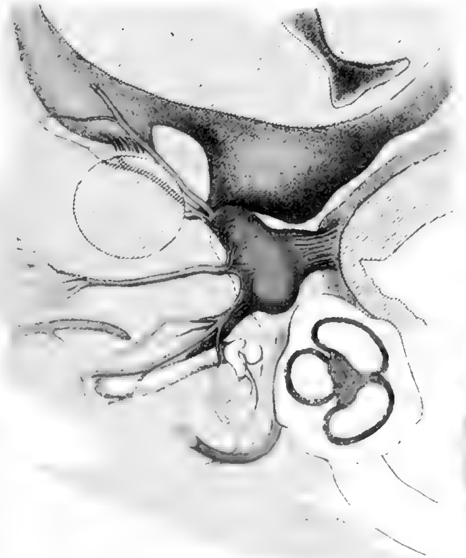
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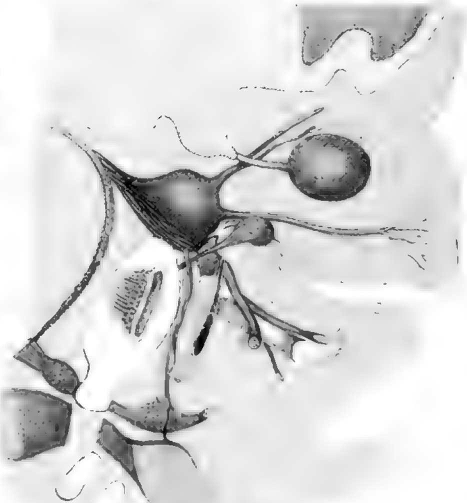
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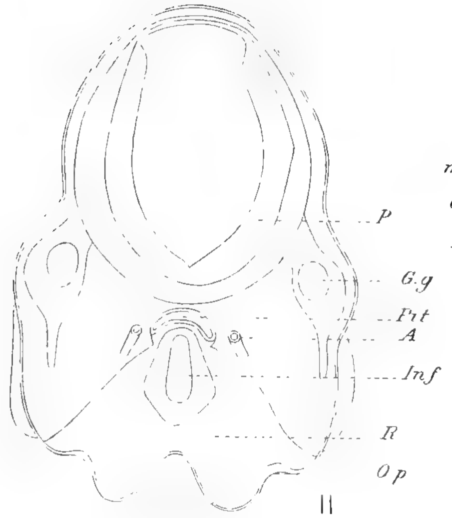

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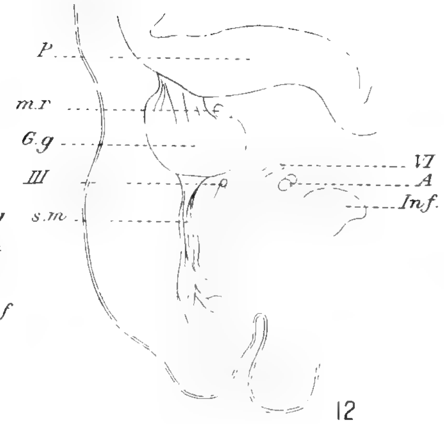

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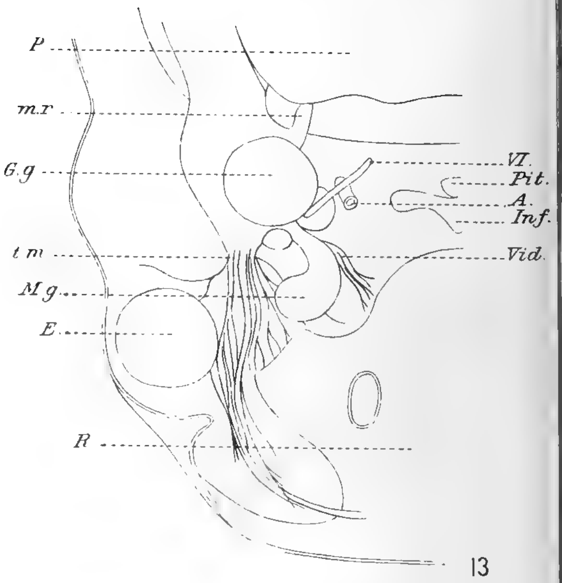

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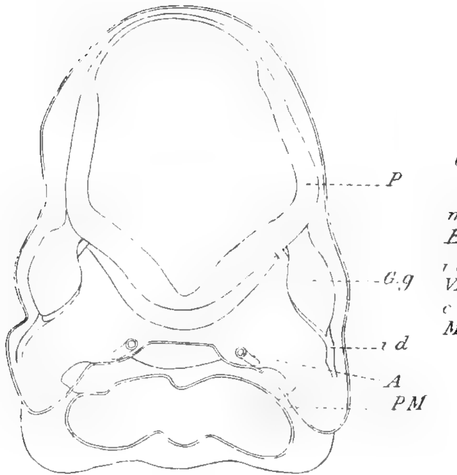

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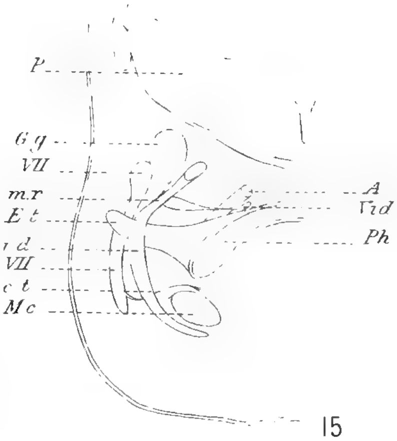

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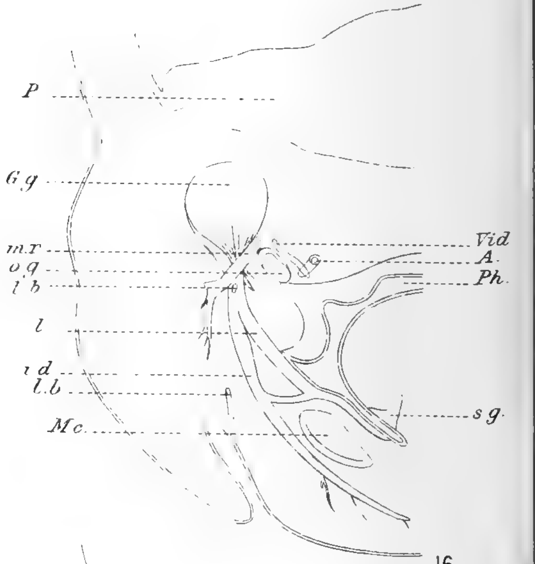

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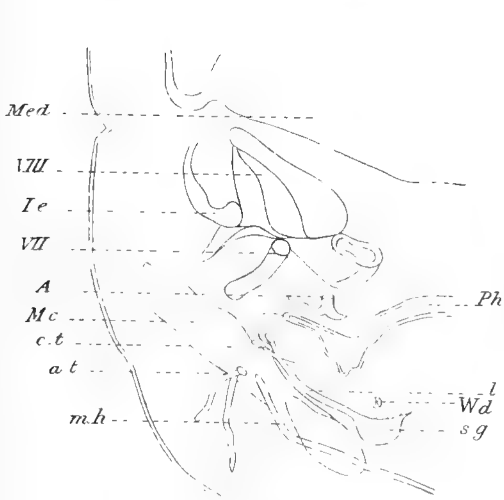

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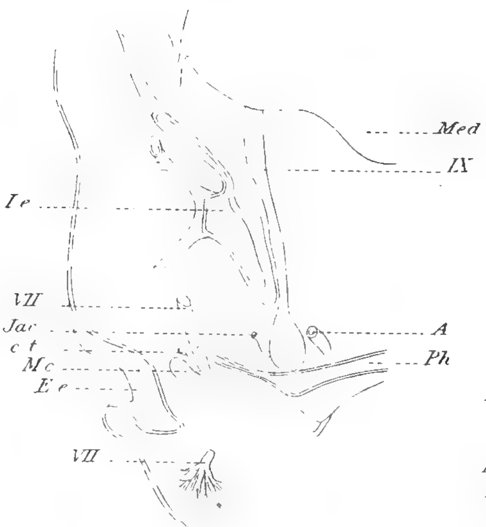

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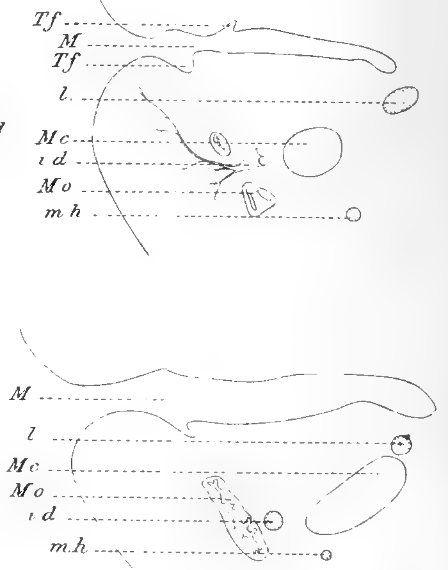

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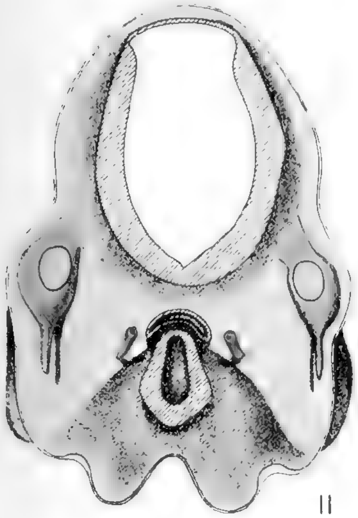

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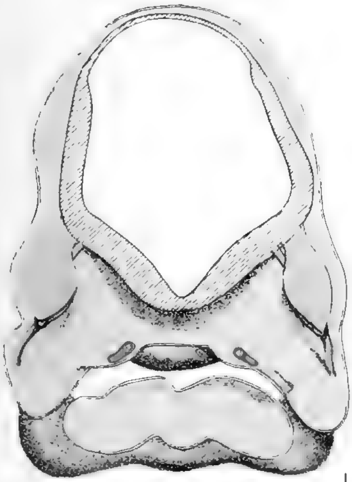

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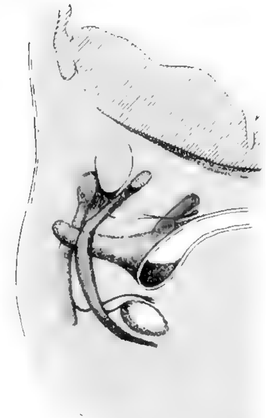

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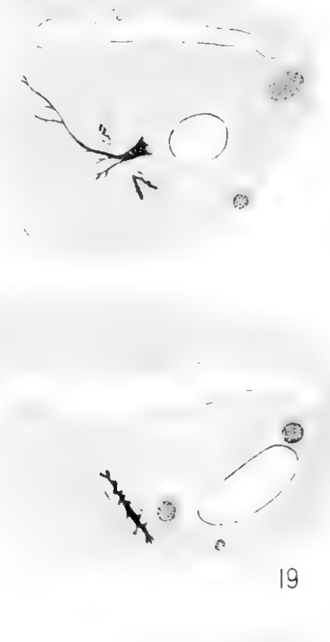

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By GRENVILLE A. J. COLE, M.R.I.A., F.G.S., Professor of Geology in the Royal College of Science for Ireland.

(Plates III. and IV.)

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By GRENVILLE A. J. COLE, M.R.I.A., F.G.S., Professor of Geology in the Royal College of Science for Ireland.

(Plates III. and IV.)

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[Read December 18, 1895.]

I.—Introduction.

The occurrence of small exposures of igneous rock in the county of Antrim, entirely differing in character from the normal basalts of the district, has long been known to field-observers. Dr. Jean Francois Berger,* of Geneva, author of so many contributions to the geology of the British Isles, paid particular attention to the "Clay-porphyry" of Tardree Mountain and of Ballycloughan, and to the glassy rocks of Sandy Braes; while Captain J. E. Portlock,† in his early surveys, came across "trachytic porphyry" in both the counties of Antrim and of Down. J. Bryce‡ was probably acquainted with this rock under the name of "grey-stone," a term commonly used for trachytes; but more than fifty years had elapsed since the publication of Berger's paper before any additional information was obtainable as to its true character. E. T. Hardman,§ on the basis of his own elaborate analysis, then placed the rock of Tardree with the rhyolites of von Richthofen; Professor Hull,‖ at a time when there were few students of thin sections, described its microscopic characters; and Mr. G. H. Kinahan ¶ subsequently referred it to the "Nevadites."

It was still reserved for a German visitor, Professor A. von Lasaulx,** to make a careful mineralogical investigation of the rock; and, even then, the remarkable

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* "On the Geological Features of the North-Eastern Counties of Ireland"; with an introduction and remarks by the Rev. W. Conybeare. Trans. Geol. Soc. London, ser. i., vol. iii. (1816), pp. 186, 189, &c.

† "On the Study of Geological Phenomena in Ireland," Journ. Geol. Soc. Dublin, vol. i. (1834), p. 9.

‡ "Geological Structure of the Counties of Down and Antrim," Report British Association, 1852, Notices and Abstracts, p. 42.

§ "On the Analysis of Trachyte Porphyry from Tardree Quarry, near Antrim," Journ. Royal Geol. Soc. Ireland, vol. iii. (1870–3), p. 32. The paper was read in 1871.

‖ Memoir to sheets 21, 28 and 29, Geol. Survey of Ireland (1876), pp. 18 and 45.

¶ "Manual of the Geology of Ireland" (1878), p. 208.

** "Petrographische Skizzen aus Irland," Tschermak's Min. u. Petr. Mittheilungen, Bd. i. (1878), p. 410.

glassy products on the high plateau of Sandy Braes, though appreciated by Berger and localised by him on his map, were allowed to remain in ill-deserved obscurity.* For some reason, the whole of the Antrim rhyolites have been commonly styled "trachytes," in treatise after treatise, down to the present day, although the name "trachyte" has been restricted to another class of lavas for more than thirty years.

Going from south-east to north-west, the exposures of rhyolite in Co. Antrim are as follows :—

(i.) *Templepatrick.*—An ill-defined area about a mile-and-a-half long, including sections in the upper levels of a chalk-quarry.

(ii.) *Tardree area.*—Exposures scattered over an area of about five by three miles, including two good quarries in Tardree Mountain, and excavations in the plateau of Sandy Braes.

(iii.) *Eslerstown.*—An obscure exposure.

(iv.) *Kirkinriola*, north of Ballymena. A similarly obscure patch along the hollow of a stream.

(v.) *Ballycloughan* (*Quarrytown*).—There is a good quarry in this mass.

(vi.) *Cloughwater.*—A small circular boss in the midst of a peat-bog, just west of the road from Ballymena to Cushendall, and one-and-a-half miles from Ballycloughan.

The grouping of these exposures suggests that we are dealing with a series of small volcanoes opened along a line of fissure. A line drawn N. 27° W., through the centre of the dome of Tardree Mountain, passes through the east end of the Templepatrick quarry on the one hand, and across the Eslerstown area on the other; it leaves Kirkinriola a mile on the left, and Ballycloughan half-a-mile on the right, and bisects the little boss near Cloughwater school. The direction of this hypothetical fissure corresponds well with that of so many of the basic dykes between Belfast and Carrickfergus, which can easily be traced out on the edge of the basalt plateau or on the shore. A similar north-north-westerly direction is common in the dykes as far north as the Giant's Causeway, and as far south as the area of the Mournes.† The rhyolitic area between Dromore and Moira, Co. Down, lies well to the south of our particular line, and is probably more nearly connected with the granite masses of the Mourne Mountains.‡

It is probable, however, that many other centres of rhyolitic eruption lie buried beneath the enormous outpouring of the Later Basalts. The conglomerates

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* Cf. Bäckström, Geol. Fören. i Stockholm Förhandl., Bd. xiii. (1891), p. 672.

† This fact was observed by Berger, "On the Dykes of the North of Ireland," Trans. Geol. Soc. London, vol. iii. (1816), p. 231.

‡ Memoir to Sheet 48, Geol. Survey of Ireland, pp. 10, 14, 16, and 37; Mem. to Sheet 36, p. 11. Also A. M'Henry, "On the Age of the Trachytic Rocks (Rhyolites) of Antrim," Geol. Mag., 1895, p. 264.

containing pebbles of rhyolite, found at Ballypalady and at the Libbert Mine, Glenarm,* are probably derived from hidden masses lying to the east of our line; and Mr. M'Henry states that he has observed similar beds at other places† in the county of Antrim.

II.—TEMPLEPATRICK.

A large mass of rhyolite, of a whitish to a pale pink-brown colour, is seen in a fine section formed by the north side of Templepatrick quarry. It lies above the chalk, from which it is separated in most places by an irregular zone of reddened flint-gravel and dark clays. The rock has a distinct and uniform fluidal structure, and breaks parallel to this, like many Icelandic examples. It contains small porphyritic grains of quartz, which are far more sparsely scattered than at Tardree, a few transparent felspars, and here and there a hexagonal plate of biotite. In contact with the gravel or the chalk, it has decomposed to a soft greenish clay, the weathering away of which has produced a horizontal groove along the quarry-face. This extreme alteration of what was probably at one time the most glassy portion of the rock is an unusual feature, and must be explained by the ease with which water can attack the material at its surfaces through the surrounding permeable strata. Something akin to this decomposition is seen in the glass of a rhyolitic andesite from Tay Bridge End, described by Professor Judd,‡ which retains its essential structures, and yet falls into powder when placed in cold water.

The rhyolite of Templepatrick has been traced by the officers of the Geological Survey to the south of the railway, and also to the west, across the churchyard. My own specimens, freshly dug up in the latter spot, differ considerably from the more boldly developed masses in the chalk-quarry. There are no conspicuous porphyritic crystals, and the fluidal structure is faint and irregular. Numerous small angular lumps of rhyolite are embedded in the mass. The specific gravity of this rock is 2·44.

A delicate shimmer appears on some of the joint-surfaces of specimens from the churchyard, and suggests the formation of silky zeolites. Under the microscope, the groundmass is seen to be exceedingly fine-grained, with abundant aggregations of globular crystallites, the "cumulites" of Vogelsang. One or two minute and colourless radial spherulites occur, and the whole seems but little

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* Sir A. Geikie, "Anniversary Address," Quart. Journ. Geol. Soc. London, vol. xlviii. (1892), *Proceedings*, p. 168. Also A. M'Henry, *op. cit.* p. 262.

† *Op. cit.*, p. 263.

‡ "Volcanic Rocks of the North-east of Fife," Quart. Journ. Geol. Soc. London, vol. xlii. (1886), p. 431.

removed from a true glass. The ferromagnesian constituent, as at the chalk-quarry, is biotite, occurring in dark little flakes, only in part identifiable. A colourless mineral, characterised by minute rectangular and, more rarely, hexagonal sections, and by low polarisation-colours, is equally abundant. A few of these crystals are simply twinned; but their small size renders the determination of their uniaxial or biaxial nature impossible. They mostly show a zonal structure, and many of their characters thus suggest nepheline. A sample of the rock was consequently roughly powdered, was boiled in concentrated hydrochloric acid, and was allowed to stand for twenty-four hours. It became thoroughly bleached; but no gelatinisation occurred on evaporation, and the same small crystals, with low polarisation-colours, remained unaltered in the residue. Hence I conclude that they are merely a form of the sanidine which prevails in the coarser varieties of the Antrim rhyolites, and their occasional twinning also supports this view. In the residue from the digestion in acid, a few grains of quartz and epidote appeared, after the finest material had been washed away.

From the variation in character of the specimens obtainable at Templepatrick, I suspect that we have to deal, as at Tardree, with a complex group of rhyolites, part only of which forms the central intrusive core. The wavy flow-structure and brecciation at the churchyard certainly suggest a lava erupted at the surface. But any pitchstones or obsidians that may exist in this area still lie hid. I do not understand the description* of the "pearlstone" found "on the upper side of the railway," which was said by Mr. Duffin to be "almost all felspar of a compact texture, and of a pearl-grey colour"; possibly the name "pearlstone" is here misapplied. Professor Hull goes on to speak of "the pitchstone of Templepatrick," possibly on the basis of Mr. Duffin's notes. For my own part, I have failed to find exposures south of the railway, and know of no glassy rock in this locality.

The mode of occurrence of the compact rhyolites of Templepatrick has given rise to some difference of opinion. In the Memoir to Sheets 21, 28, and 29 of the Geological Survey of Ireland, published in 1876, no reference is made to the remarkable sections in the chalk-quarry. The wells referred to on p. 21 of the memoir are now both closed; but the existence of the rhyolite beneath the churchyard is still proved, as we have seen, whenever graves are dug. The critical sections are certainly at the present time in the large quarry; but the representation of these in the longitudinal section,† published in 1891, is hardly satisfactory. A large dome of rhyolite ("Trachyte porphyry") is shown south of the railway, while the mass exposed in the quarry is represented as an isolated fragment. It may be observed that the earlier sections of the Irish Survey were

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* Memoir to sheets 21, 28 and 29, Geol. Survey of Ireland, p. 21.

† Geol. Survey of Ireland, Long. Sections, Sheet 31.

remarkable for the caution with which underground features were hinted at, rather than sketched in. Some of the more recent sections seem to err, on the other hand, in a certain picturesque boldness, for which there may be only limited authority in the accurate notes taken in the field.

Mr. G. H. Kinahan,* in 1878, regarded the rhyolite at Templepatrick as intrusive; but the first reference to the importance of the section was made in a communication from Mr. M'Henry to Sir A. Geikie,† in which the "trachyte" was stated to be intrusive in the Lower Basalts, but to be itself pierced by younger basic dykes. Professor Hull‡ subsequently published a drawing of the eastern half of the section, and maintained that the basalt was intrusive in the rhyolite. Mr. M'Henry§ has now given us a concise exposition of his views, with drawings of the whole northern face of the quarry. His arguments may be thus summarised:—

(i.) The rhyolite ("trachyte") at the east end is intrusive in the adjacent basalt, because it has a columnar structure, radiating inwards from the curved surface of junction, with a flow-structure also parallel to that junction. The flint-gravel in contact with it, and, in fact, between it and the basalt, is indurated, in contrast with its usual loose and more clayey character. (In the figure in the second paper cited below, the word "Basalt" should be transferred from the chalk on the left to the mass in the right-hand upper corner.)

(ii.) At the west end, the rhyolite "has forced its way underneath the basalt along the zone of the flint-gravel bed, which it carries on its back, and at one place portions of the gravel bed rest both above and below it."

(iii.) At Ballypalady, the Libert Mine, and other places, conglomerates occur between the Upper and the Lower Basalts. These contain pebbles and finer débris of rhyolite, and, at Ballypalady, fragments from the Lower Basalt in addition.||

After the appearance of Mr. M'Henry's paper, Professor Hull kindly sent me some further comments upon the section; and, with the advantage of the company of Miss S. M. Thompson and Mr. R. Welch, I revisited the Templepatrick quarry, feeling that conclusive evidence could be found only in the western portion of the section. At the east end, the junction of the rhyolite, gravel, and basalt is not

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* "Geology of Ireland," p. 162.

† A. Geikie, "Volcanic action, &c.," Trans. Roy. Soc. Edin., vol. xxxv. (1888), p. 171.

‡ "Physical Geology and Geography of Ireland," 2nd ed. (1891), p. 99.

§ "On the Age of the Trachytic Rocks (Rhyolites) of Antrim," Geol. Mag., 1895, p. 260. Also "Sketch of the Geology of Co. Antrim," Proc. Geol. Assoc., vol. xiv. (1895), p. 141.

|| These "trachytic agglomerates" were previously referred to by Sir A. Geikie, "Anniversary Address," Quart. Jour. Geol. Soc. London, vol. xlviii. (1892), *Proceedings*, p. 168.

now exposed exactly in the form shown in Mr. M'Henry's section; but the rude columnar jointing of the rhyolite certainly supports his argument. It might fairly be urged, however, that the rhyolite flowed against a gravel bank, which was subsequently invaded by the basalt. The bold basaltic dykes in the quarry might tempt one, indeed, to regard the basalt on the north face as similarly intrusive; on the other band, its delicate amygdaloidal character points to its being a portion of a lava-flow. I cannot agree with Mr. M'Henry that "the most important point in the evidence" is to be found at the eastern end of the north face; two rival interpretations there seem possible.

By the kindness of Dr. H. Woodward, F.R.S., editor of the "Geological Magazine," I am enabled to reproduce Mr. M'Henry's excellent figure of the western section (fig. 1), which requires more attention than he himself has drawn to it. In the field, it was necessary to prepare a clean surface of the rocks, and to clear away a certain amount of débris, before the whole of Mr. M'Henry's details could be verified. The rhyolite certainly lies between two layers of the old flint-gravel, which are fairly continuous, while a long tongue of decomposed rhyolite runs upwards on the right, closely mingled with fragments of basalt and with the characteristic reddened flints. The features along this plane are those of a fault-breccia rather than of a thin intrusive sheet; and a long crack traversing the rhyolite farther down, in continuation of the plane of the breccia, is filled with dark clay, and also suggests a surface of movement. The occurrence here of an inclined fault, with a downthrow to the west, would account, moreover, for the form of the basalt patch above the rhyolite, which now exhibits a triangular exposure on the quarry-face, the apex pointing downwards. The left side of this inverted triangle is formed by the original junction of the base of the basalt and the flint-gravel over which it flowed; while the right-hand side is formed by the

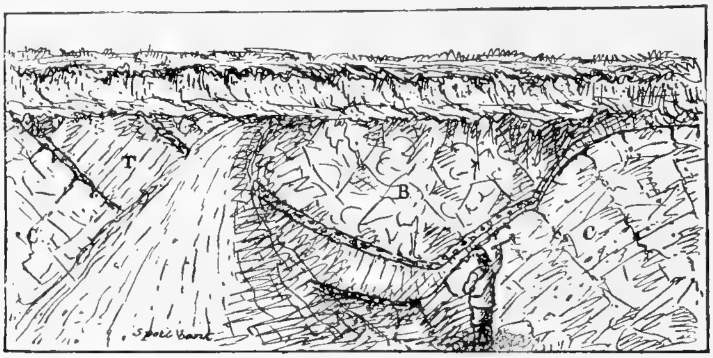

Fig. 1.
Section at west end of Templepatrick Quarry. Drawn by A. M'Henry, M.R.I.A.
B—Basalt. **C**—Chalk. **G**—Flint-Gravel. **T**—Rhyolite.
Superficial deposits occupy the top of the section.

plane of faulting, along which the basalt, gravel, and rhyolite have become dragged out and intermingled. On this plane the basalt and chalk come at one point into contact, without the intervention of rhyolite or flint-gravel.

The occurrence of a fault here in no way affects the question of the intrusive nature of the rhyolite. The layer of gravel above the rhyolite is distinctly indurated by it, the junction being marked by a continuous band of reddened flints, about an inch thick, which is unlike any other layer in the gravel. An unusual number of small cracks traverse the interior of the flints that lie along this upper plane of contact.

The gravel is less continuous on the under side of the rhyolite, between the latter and the chalk, and occurs more in lumps and patches; this feature is repeated, but on a bolder scale, at the east end of the quarry-section.

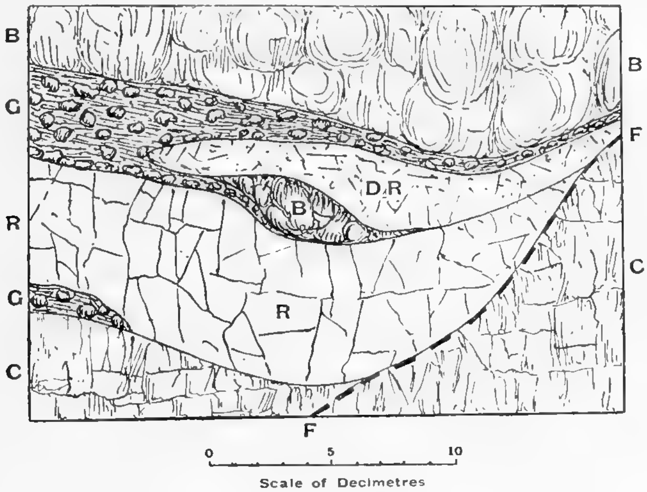

Fig. 2.

Detail of section at west end of Templepatrick Quarry.

B—Basalt. **C**—Chalk, much disturbed near junction. **D.R**—Decomposed Rhyolite. **F F**—Supposed Fault. **G**—Altered Flint-Gravel and Dark Clays. **R**—Rhyolite.

The details of that part of the western section which lies below the letter B in Mr. M'Henry's drawing afford interesting evidence of the relation of the rhyolite, not only to the gravel, but also to the basalt. A lenticular lump of basalt, of the same character as the main mass above, occurs there almost surrounded by rhyolite (fig. 2). The latter rock is greatly decomposed between the upper flint gravel and the lump of basalt, and forms a greenish and whitish friable mass. But it is continuous with a rock on the right, which is clearly the rhyolite *in situ*, and also with the fluidal rhyolite below. The clay-filled crack, above referred to, crosses obliquely upwards from the basalt-lenticle towards the brecciated prolongation of the rhyolite. Careful examination of the pale friable material above the lump of basalt shows that it consists largely of greenish clay, similar to that which is so marked a feature of the decomposed rhyolite along the junction of its lower surface and the chalk. This clay breaks up along small close-set joints, which may be those of the original glassy selvage of the rhyolite. On washing it for some time in water, numerous small angular lumps remain, of more resisting character; these prove to be cores of altered rhyolite which have held out against complete decay. A few microscopic fragments of reddened flint also occur, which have become embedded from the associated gravels. The finer portion of the residue, after washing off the mud, shows tiny lumps, probably of the original groundmass, altering into clay, and fresh flakes of orthoclastic and plagioclastic felspars, which are similar to those in the massive rhyolite. For comparison, pieces of the rhyolite were powdered to a similar degree of fineness. But the decomposed rock in one point differs markedly from the unaltered rhyolite. It abounds in minute prisms and granules, with a high refractive index, the measurable angles and extinctions of which prove them to be epidote. This mineral is clearly, as at Tardree, an accompaniment of the decomposition of the rhyolite.

Thus we have, in about a vertical metre of the section, proof that the rhyolite, when oozing in among the gravels, encountered the pre-existing basalt also, and carried off at least one lump of it as a record.

I think, then, that the relative ages of the rhyolite and the basalt at Templepatrick may be considered as well established. The third division of Mr. M'Henry's argument, as I have summarised it above, merely shows that the rhyolites are older than the period of rest marked by the pisolitic iron-ores of Co. Antrim. Denudation might have reached down through the Lower Basalts to pre-existing rhyolitic material, and so might have produced the conglomerates of Ballypalady and the Libbert mine. So far as I am aware, the fact that the rhyolites of the county of Antrim are younger than the Lower Basalts is nowhere demonstrated except in the difficult sections at Templepatrick.

It has been recorded, as we have already seen, that the rhyolite of Templepatrick is "pierced by younger basic dykes." This statement, however, possibly refers to the Tardree area. None of the dykes at Templepatrick, so far as I can observe, are seen in contact with the rhyolite.

III.—Carnearny, Tardree, and Barnish.

In a recent paper * I have dealt with the general features of this extremely interesting area, and have urged that the dome of Tardree Mountain represents a volcanic core, from which true lavas flowed, forming the plateaus to south and north. This same view was put forward by von Lasaulx,† who arrived at it after

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* "The Volcano of Tardree, Co. Antrim," Geol. Mag., 1895, p. 303.

† "Aus Irland" (1878), p. 167.

a somewhat limited survey of the ground. So little attention, however, has been called to the sections on the east side of Carnearny and on Sandy Braes, that Sir Archibald Geikie [*] in 1888 omitted the glassy rocks of the area from his main account of the Tertiary pitchstones of the British Isles, and only referred to them in passing on a subsequent page of his memoir. He stated, moreover, that he knew of no case where acid lavas had reached the surface during the Tertiary era, excepting at the Sgùrr of Eigg. Mr. G. H. Kinahan similarly passes over the glassy and fluidal rocks in his "Manual of the Geology of Ireland," as also does Mr. Teall in his comprehensive "British Petrography," published in 1888. The predominance, moreover, which the type-rock of Tardree Mountain has assumed in the minds of geologists is shown by the general reference of the rhyolites of the county of Antrim to massive intrusions rather than to dykes and lava-flows.[†]

The typical rock is cut into by a series of quarries extending from south to north along the flank of Tardree Mountain for a distance of more than a mile. In the acute north-western angle of the cross-roads between Carnearny and Tardree Cottage there are two abandoned diggings, which reveal a strongly reddened compact rhyolite of the central type, and also, as Mr. A. G. Wilson pointed out to me, pumiceous and perlitic obsidians, with large porphyritic crystals of felspar.

Beyond the Cottage there is at present a roadside cutting, which shows how a red colour, often vivid, has been introduced into the rhyolite along vertical joints. Hence the prevailing colour at the cross-roads is probably also due to alteration.

Immediately to the north of the roadside-cutting is an old weathered excavation, showing vertical columns 40 to 45 centimetres in diameter, which have been figured on p. 20 of the Survey Memoir. Then we pass to the important quarry in which the stone is still being actively worked for building purposes.

Here the rock is divided by great upright parallel joints into vertical or slightly curving sheets, the edges of which at first give a false effect of columnar structure. True columns occur, however, in the central part of the quarry. The same appearance is conspicuous on the craggy wall of the Bořen of Bilin in Bohemia, on the domes of Sellnitz and Zlatnik, and on others of those extraordinary necks of phonolite which penetrate the Oligocene Brown Coal. On the vertical sides of the Zlatnik Mountain the joints radiate from a centre, the mass suggesting

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[*] "The History of Volcanic Action during the Tertiary Period in the British Isles," Trans. Roy. Soc. Edin., vol. xxxv, pp. 145, 146, and 171. Also "Anniversary Address," Quart. Journ. Geol. Soc. London, vol. xlviii. (1892), *Proc.* p. 168.

[†] See, for instance, H. Bäckström, "Beiträge zur Kenntniss der isländischen Liparite," Geol. Fören. i Stockholm Förhandl., Bd. xiii. (1891), p. 672.

a book partly opened and set up on end. In this way the edges always face outwards, and are seen one after another as the observer walks round the volcanic neck. It is interesting to find the structure of these trachytic cores of Bohemia repeated thus boldly at Tardree; the rock in both cases was probably of similar viscid character, weathering out at length as a coherent dome, bounded by a wall of cliffs. At Tardree Mountain the northern climate and the greater antiquity of the mass have now combined to soften down its flanks and to cover them with grass-grown taluses. (Pl. III., fig. 1).

Oblique cross-joints may also be seen, breaking up the vertical sheets. In the second large quarry, south-west of the inn on the road from Doagh, similar features occur, with some attempt at the formation of columns 60 to 70 centimetres in diameter.

The rhyolite of Tardree Mountain, when freshly quarried, is full of water and of a deep grey colour, turning to white on drying. Hence specimens of the curb-stones and other blocks, when broken in the quarry after being shaped, may appear white on the surface and still damp and grey within.

The type-rock itself, the pale grey mass of the well known quarries at Tardree, has been frequently examined and described. Berger* styled it a "Clay-porphyry," the "porphyry of Sandy Brae," containing embedded in it concretions of smoky quartz, earthy and glassy crystals of felspar, and olivine. The "olivine" may perhaps refer to epidote. He determined the specific gravity of the rock as 2·43; Mr. Hardman† subsequently gave 2·433; and I have obtained 2·46. It will be seen later that these figures are probably too low, owing to the abundance of minute drusy cavities.

In calculating the proportions of the mineral constituents of the rock, Hardman regarded it as consisting of quartz and orthoclase only. Von Lasaulx‡ recorded his discovery of tridymite in the rock, and stated, in his popular work,§ that the fine dissemination of this mineral through the groundmass accounted for the high percentage of silica found by Hardman. At the same time he described the groundmass as rich in glass, thus agreeing with Prof. Hull,‖ who had previously regarded it as "amorphous." But von Lasaulx, for some reason, in his formal paper,¶ states that, "contrary to Prof. Hull's opinion," the groundmass shows no glass, but is a very compact mixture of quartz, tridymite, and felspar, the last-named mineral not affording proof of its monoclinic or triclinic

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* *Op. cit.*, Trans. Geol. Soc. London, ser. i., vol. iii., p. 189.

† *Op. cit.*, Journ. R. Geol. Soc. Ireland, vol. iii., p. 27.

‡ "On the discovery of Tridymite in the Trachyte Porphyry of Co. Antrim," Journ. R. Geol. Soc. Ireland, vol. iv. (1877), p. 227.

§ "Aus Irland," pp. 167 and 168.

‖ Memoir to Sheets 21, 28, 29, Geol. Survey of Ireland (1876), p. 18.

¶ Tschermak's Mittheilungen, Bd. i. (1878), pp. 416 and 418.

character. In a later passage he even styles the structure microgranitic. Mr. J. J. H. Teall* again reversed von Lasaulx's decision, pointing out that the matrix could not be resolved, and could only be described as cryptocrystalline.

Von Lasaulx described the rock as a *quarzsanidintrachyt*† or *quarzsanidinrhyolit*,‡ and enumerated, as the crystalline constituents, grey and black quartz, sanidine, small laths of plagioclase (determined as andesine by their extinction-angles), dark mica, tridymite, magnetite, epidote, and apatite. Dr. Bettendorf§ supplied an analysis of the sanidine, showing it to be distinctly a soda-orthoclase, such as commonly occurs in rhyolites. The soda, indeed, constitutes 5·44 per cent. of the sanidine, and the potash 8·61 per cent. Prof. Hull‖ had previously shown the presence of dark mica, and hornblende is recorded both by Mr. Hardman and Mr. Watts.¶ The latter writer regards the plagioclase that is present as albite, and adds zircon, rutile, and sphene as constituents of the rhyolites of this area.

The typical rock was analysed in 1871 by Hardman,** who reported an unusually high proportion of lime, and a correspondingly low amount of alumina. He believed that lime had been imported into the mass during its alteration. Dr. Bettendorf found 1·21 per cent. of lime in the porphyritic orthoclase; and von Lasaulx pointed to this mineral, and to the epidote formed at its expense, as the source of Hardman's 7 per cent. of lime in the rock as a whole. Prof. J. Roth,†† while commenting on the low amount of alumina, placed the rock, with Hardman, among the liparites or rhyolites. Mr. Player,‡‡ however, subsequently obtained results differing markedly from those recorded for the alumina and lime, but agreeing closely as regards the other constituents. We may take his analysis, then, as that of the normal rock, which thus becomes a representative rhyolite. It is well to again emphasise this fact, since the rock of Tardree has been so freely called a trachyte, a trachyte-porphyry, and even a trachyte-porphyrite. The fragments of highly silicated lavas, on the other hand, found in Mull,§§ with specific gravities of 2·45 to 2·50, and of similar age to the rhyolites of the county of Antrim, remain among the very few representatives of true trachyte in our islands.

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* "British Petrography" (1888), p. 348.

† Tsch. Mitth., 1878, p. 418.

‡ "Aus Irland," p. 167.

§ Tsch. Mitth., 1878, p. 417.

‖ "Mem. Geol. Survey," Sheets 21, 28 and 29, p. 18.

¶ Watts, "Note on the Occurrence of Perlitic Cracks in Quartz," Quart. Journ. Geol. Soc. London, vol. l., p. 368; and M'Henry and Watts, "Guide to the Collections of Rocks and Fossils, Geol. Survey of Ireland" (1895), p. 80.

** *Op. cit.*, p. 29.

†† "Beiträge zur Petrographie der plutonischen Gesteine" (1873), pp. 111 and xxxii.

‡‡ See Teall, "British Petrography" (1888), p. 348.

§§ G. Cole, "Note on the Gravel of Ardtun," Quart. Journ. Geol. Soc. London, vol. xliii. (1887), p. 277

Mr. Player's analysis of the rhyolite of Tardree is as follows:—

Silica	76·4
Alumina	14·2
Ferric oxide	1·6
Lime	·6
Potash	4·2
Soda	1·8
Water	1·5
	100·3

Hardman found ·295 per cent. of magnesia and a trace of phosphoric acid.

In addition to the previous petrographic descriptions of the central rhyolite of Tardree, I may state that sections show a multitude of "globulites" and "cumulites," associated with the delicate colourless rods that form so much of the groundmass. There can be no doubt that the rock, like that of Templepatrick churchyard, is on the verge of becoming crystalline throughout; but the above features point equally clearly to the existence of a residue of glass. A micro-granular structure appears between crossed nicols, which may be due merely to the distribution of minute crystals, hidden in the glass; but it suggests that much of the glass has broken up in the end into crystalline grains after the primary separation of the crystallites from it. Such a structure appears in some of the spherulitic rocks of Arran,* and in those of older date which have become devitrified, as at Wrockwardine in Shropshire; in such cases the primary structures are not obliterated by this final change. A specimen which I collected N.W. of Skleno, near Selmeczbánya in Hungary, is spherulitic throughout, and closely resembles the rock of the Corriegills shore in Arran; but extinction takes place in conformity with the spherulitic rays, and there is no trace of granulation. Perhaps the latter is always a secondary structure, but may be induced at no long interval after the consolidation of the lava, should it again come under conditions of high temperature, such as are known to be favourable to devitrification.

In one of my sections from the Tardree mass, two disrupted and almost opaque bodies appear (Pl. IV., fig. 1), which can be little else than injured spherulites. These may have been formed in the first stages of cooling, and may have been broken up, and in part redissolved, during a subsequent period of flow.

Idiomorphic biotite is the usual ferromagnesian constituent; but soda-pyroxene might reasonably be expected in a rock of this class. It occurs, as we shall presently see, in a glassy lava on Carnearny, and in some of those on Sandy Braes.

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* The rock from the shore at Corriegills, for instance, described by Bonney, "On certain rock-structures, as illustrated by Pitchstones in Arran," Geol. Mag., 1877, p. 506; and by Teall, "British Petrography," p. 346, and pl. xxxix., fig. 1.

In this prevalence of biotite, the majority of the Antrim rhyolites ally themselves to those of Selmeczbánya in Hungary, and not to the Icelandic examples, which contain pyroxene.* The few examples of porphyritic plagioclase that I have been able to study include among them only one which yields symmetrical extinctions on either side of the composition-plane of the twin-lamellæ. Von Lasaulx obtained an angle of 5½°; and this example gives 4½°. Mr. Watts† is probably justified by wider observations in recording the occurrence of albite. It seemed desirable to inquire further into the nature of the plagioclase, and to complete the study of this interesting rock, by a dissection of the mass after the manner of Cordier. The microscope had already shown how singly and repeatedly twinned felspars are present in about equal proportions; at any rate, if some twenty different crystals are broken up from various parts and various specimens of the rock, a large number must be plagioclastic. Moreover, two cases were found in which the minute twin-lamellæ were visible on the surface of the crystals with a lens. These, and other fragments obtained by direct selection or by sifting, were thrown into a diffusion-column of methylene iodide. One solitary flake, which may, after all, have been a chip of quartz selected in error, sank to the level of 2·68; if this were a true felspar, it indicates the presence of andesine or even labradorite. But all the other cleavage-flakes of felspar that were examined, including the two actually determined as plagioclastic, swam at from 2·57 to 2·58, there being a fair division into two series having these specific gravities respectively. The conclusion is that the monoclinic and triclinic felspars present are very closely allied species, and that we are on the critical line where any increase in the albite-molecule transforms soda-orthoclase into the anorthoclase of Förstner. Carlsbad twinning being a possible structure in anorthoclase, some of the so-called "sanidines" of Tardree may even prove, on further examination, to be triclinic. We may safely regard the bulk of the repeatedly twinned felspars as anorthoclase, with here and there an albite, which may be revealed by the observation of symmetrical extinctions.

The lithoidal groundmass of the Tardree rock has a specific gravity of 2·566; so that the specific gravity of the rock-mass, already recorded as 2·43 to 2·46, must be attributed to the abundance of drusy cavities, lined with tridymite, which are too small to be eliminated.

Where drusy cavities of fair size occur in the rock, tridymite may easily be recognised, often coated with a brownish or a greenish crust. The anisotropic character of the hexagonal plates can be seen under the microscope, the colours being low greys, like those of leucite. On the surface of each crystal are a number of minute discoidal bodies, slightly yellowish, which also cluster along its

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* Bäckström, *op. cit.*, Geol. Fören. i Stock. Förhandl., Bd. xiii., p. 637.

† M'Henry and Watts, *op. cit.*, p. 80.

margins. These are probably what von Lasaulx* described as an alteration-product, resembling hyalite. Their mode of occurrence certainly suggests a deposit of iron-stained opal; but the material gives fairly vivid colours, even of the second order, between crossed nicols, although it is of very trifling thickness. The hexagons of the tridymite from the browner cavities of the rock are thus seen to be ringed about with a coloured and brighter margin. This doubly refracting substance is that which has developed as a crust on the surface of the drusy cavities after the formation of the tridymite. In the hand-specimen, the crust is seen in many cases to consist of epidote, and its occasional brown colour may, after all, arise from associated limonite. The marginal zone is absent in the tridymite extracted from the colourless druses. Von Lasaulx has pointed out that minute crystals of quartz may also be obtained from these cavities.

Here and there far smaller druses appear in microscopic sections (Pl. IV., fig. 1). They may be some ·3 mm. in diameter, with platy crystals, of weak double-refraction, projecting from their walls. These crystals are also referable to tridymite, and sometimes this mineral has completely filled the cavity, or the end of it traversed by the section. Precisely similar microscopic druses occur in the compact and banded rhyolite at Hlinik in N.W. Hungary, the "millstone-porphyry" of older writers.

In one of the Tardree druses, a delicate needle, with oblique extinction, is the only crystal present, and this I hold to be a felspar. Other crystals in these drusy cavities are probably minute sanidines of the Templepatrick type; and the occurrence of the cavities themselves may form an interesting link between the central mass of Tardree and the drusy granites and eurites, the so-called "granophyres," of the Mourne Mountains and the Inner Hebrides. Professor Hull † has opposed any such comparison; but Mr. M'Henry ‡ has distinctly supported it, and has pointed to the neck of rhyolite ("trachyte porphyry") between Dromore and Moira, Co. Down, as occupying an important position midway between Tardree and the Mournes.

In these petrographic notes, the occurrence of black manganese stainings and of minute plates of hæmatite should be recorded. The latter are found abundantly as black glancing specks in the groundmass; and they occasionally form clusters in the cavities, which are then stained delicately pink. If they are crushed with a knife-point, their strong red streak becomes apparent.§

In the specimens in the Royal College of Science for Ireland, as well as in

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* *Op. cit.*, Tscherm. Mittheil., Bd. i., p. 412. Also Journ. R. Geol. Soc. Ireland, vol. v., p. 31.

† "Phys. Geol. and Geogr. of Ireland," 2nd ed., p. 97.

‡ *Op. cit.*, Geol. Mag., 1895, p. 264.

§ Mr. Watts (*op. cit.*, Quart. Journ. Geol. Soc. London, vol. l., p. 373) has observed specular iron in cracks in the obsidian of Sandy Braes.

those collected by myself, epidote is rare on the whole, but is distinctly visible as vivid granules, as a coating to some of the cavities, and in the green bands that run across some altered portions of the rock. I have not come across zones of this mineral round the quartz crystals, such as von Lasaulx observed in his microscopic sections. Its occurrence as a crust upon the tridymite has been noted above in the microscopic description of the rock.

The distance to which the type-rock of Tardree Mountain extends from the central dome is a point difficult to settle in the field. The whole boundary of the rhyolitic area is conjectural,* owing to the dense and continuous layer of peat and heather that covers this undulating moorland. Even where farming has reclaimed portions of the surface, the roads are still of the steep highland character, and seldom cut deeply enough into the hillsides to expose the underlying rock. But the rhyolites have a marked fluidal structure, and strongly suggest lava-flows, as we recede from the denuded core of Tardree Mountain. This feature has been noticed at Browndod (1½ miles distant) on the south-east; at Scolboa (1½ miles) on the south; emphatically in the hollow east of Carnearny (1¼ miles south-south-west of Tardree); and equally strikingly in the townland of Barnish, only ¾ mile from the central mass. If these rhyolites are lava-flows, the Tardree type of rock may still be found underlying them, and even intruding into them. Away in the south-west (2¼ miles), nearly half-a-mile south of the Covenanters' Meeting-House, on the hill-road from Antrim to Kells, there is an exposure of compact grey rhyolite, decomposing to brown, seen in the low cliff of a disused quarry. This rock, in microscopic section, shows an almost microcrystalline groundmass, full of minute transparent rods of felspar, and stained by oxides of iron and manganese, which have spread inward from the numerous joint-surfaces. The porphyritic crystals are quartz, orthoclase, and plagioclase, the last-named being unusually prevalent and greatly corroded by the once glassy groundmass. A ferromagnesian mineral has been sparsely present, but has decomposed to mere chloritic patches. Tridymite lines the minute cavities in the section. The characters of this rock resemble those of the central mass at Tardree rather than of the surrounding lavas, and it may be merely a westerly offshoot from the neck.

The rocks at the cross-roads south of Tardree Cottage seem to represent flows both of glassy and lithoidal rhyolite; lamination is also recorded† from the braes east of Carnearny, where the compact grey and brown rhyolite rises as a considerable hill, actually higher than Tardree Mountain. Certainly, a continuously fissile structure is very apparent in this mass, though it might be overlooked in

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* Compare Hull, "Phys. Geol. and Geogr. of Ireland," 2nd ed., p. 98. The area is fairly represented on the map accompanying Berger's Paper (Trans. Geol. Soc. London, vol. iii., 1816, pl. 8), though the name "Brown Dod" is misplaced.

† Mem. to Sheets 21, 28 and 29, p. 19.

the rubbly exposures in the road upon the south. A small plantation now runs along the east side of the little valley which divides this crest from Carnearny. On the west side, however, the same fissile rhyolite is clearly marked along a line of miniature cliffs. Possibly this is the spot represented in fig. 4 of the Survey Memoir, which is not localised, and which is described as "Quarry of Trachyte porphyry and Rhyolite." As the word "rhyolite" is not used elsewhere in the memoir, it is impossible to know the type of rock to which, in this instance, it was intended to refer.

However, two types are shown in juxtaposition in this interesting valley-side. The planes of division here dip about 10° westward, the Tardree *massif* lying to the north-east. The upper part of the section is composed of lithoidal rhyolite, like that of the opposing brae, weathering in a platy fashion, and with the usual porphyritic crystals; the lower part is dark, and at first sight resembles the basaltic boulders of the slopes of Carnearny. Outwardly, however, it reveals spherulitic and perlitic structures, and, when chipped, at once proves to be a deep grey pitchstone, containing handsome brown spherulites, which are from 4 mm. to 20 mm. in diameter. On fracture, they appear somewhat dull and earthy.

In microscopic section, these spherulites are only slightly differentiated from the glass, like those in some Icelandic rhyolites, or in the fluidal pitchstones of Zwickau, or—a still more striking instance—in the well-known lithoidal andesite of the Stefanschacht near Selmeczbánya. They are darker in colour than the ground, from which they may be divided by a shrinkage-crack. They have no radial structure, and are simply more crystalline knots in the matrix, which have already begun to undergo some oxidation and decomposition.* (Pl. IV., fig. 2).

The matrix is perlitic, the main cracks being iron-stained; but the spiral cracks are waved and irregular, not clean and sharp as usual. It is impossible to ascertain that they actually traverse any of the microlites of the groundmass, and I believe that their irregularity is due to their being interfered with by the larger of these tiny prisms, and by groups of them. The microlites consist, firstly, of rods of felspar, in many cases bifurcated at their growing ends and square in cross section; secondly, of far smaller prisms of pale green pyroxene, some of them showing the re-entrant angle at one end, due to twinning on the orthopinacoid. These pyroxenes alter to a yellow colour before the felspars exhibit any change. Thirdly, magnetite is fairly abundant. The glass in which the microlites lie is pale brown and singularly pure; a few globulites alone appear in it, often arranged in lines. The microlites, however, form a far larger part of the groundmass than does the glass.

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* Compare G. Cole, "On Hollow Spherulites," Quart. Journ. Geol. Soc. London, vol. xli. (1885), pp. 165 and 166.

This pyroxenic character of the rock is borne out by the porphyritic crystals. The order of prominence in these is plagioclase, orthoclase, quartz, soda-pyroxene, magnetite, and zircon. The plagioclase shows both albite and pericline twinning, and is bored through and through by glass intrusions; it is thus often reduced to a mere shell, two walls of the prism, with the angle between them, sometimes alone remaining. It often includes the pyroxene, as the pyroxene does magnetite, he three minerals forming "glomeroporphyritic" groups. The simply twinned felspar behaves like the plagioclase with regard to the pyroxene, and the two felspars evidently arose in the same original rock. The quartz resembles that of the other rhyolites, and is traversed by curvilinear cracks. The pyroxene developed very little earlier than the plagioclase, so as to form at times intergrowths that are almost micropegmatitic. The spreading and branching groups of pyroxene, however, are in these cases granular in structure, and are not optically continuous. Face-pleochroism is not perceptible in thin sections of the pyroxene, and the axis-colours differ but little from one another, changing from a pale yellow-green to a slightly bluer green. We may safely refer this mineral to the soda-augites poor in iron. Detached prisms and granules of it, including magnetite, occur freely.

Magnetite is also fairly abundant, and in one instance includes zircon; the latter mineral is by no means rare, and even its uniaxial character can be determined. A few granules of epidote are seen, collected in one hollow in the section.

This pitchstone is, then, a glassy pyroxene-rhyolite on the verge of the rhyolitic andesites. In a previous consolidation, as shown by the porphyritic groups, it was in the form of a pyroxene-plagioclase-granite; whereas the rock at present hidden beneath Tardree Mountain is probably a more ordinary mica-granite. Since the Carnearny pitchstone underlies the normal Tardree-type of Rhyolite, it may be that the earlier eruptions were more andesitic than the later ones. This would imply, also, a gradual change, leading from any previous basaltic conditions in the area up to the remarkable obsidians of Sandy Braes. However, it is rash to found so wide a generalisation on this interesting but solitary section on Carnearny.

The pitchstone of Carnearny has a specific gravity, in the mass, of 2·44. The glassy and microlitic groundmass, determined in a diffusion column of methylene iodide, gives 2·42 to 2·44. A fragment of one of the spherulites is as high as 2·61, but their average specific gravity is 2·544; a large one, detached and determined on Walker's balance, gives 2·56. The determination of the specific gravity of the felspars is vitiated by the frequency of more basic inclusions; but the glass-inclusions in others may serve to balance these. The results, yielding an average of 2·65, and pointing to oligoclase, are thus probably somewhere near the mark.

I have no doubt that this glassy rhyolite forms part of a lava-flow, comparable to those in the Tepla valley, between Skleno and Hlinik, where perlites* and pitchstones are exposed in cliffs more than a hundred feet in height.

Since the plane of junction between the pitchstone and the overlying lithoidal rhyolite is parallel to the planes of fissility in the latter, it is highly probable that the fissile structure is here an indication of flow. Unlike the rock of Templepatrick, however, there is no delicate banding present to emphasise and confirm this observation.

If, however, we stand at the Tardree Inn, and look up, somewhat towards the right, at the steep brae on the north, a pale quarry is seen on the road rising to Sandy Braes. We have here a crumbling and altered rhyolite, with the most beautiful banded structure; its general colour is pink, with yellower layers, and the flow-planes, as seen in this east-and-west section, are horizontal or gently undulating. The rock goes to pieces under the hammer, and reminds one, in some ways, of the altered rhyolitic andesite of Tay Bridge End, to which reference has already been made. (Pl. III., fig. 2.)

We are now in the townland of Barnish, which includes the plateau of Sandy Braes, certainly one of the most interesting spots for the geologist in the whole of Ireland. Berger† long ago examined on this spot "pitchstone porphyry" and "pearlstone porphyry," and Portlock‡ referred to the "mineral" pitchstone as "abundant in the porphyry of Sandy Braes, accompanied by Pearlstone." Von Lasaulx§ knew these glassy rocks only in collections, styling them *Obsidianporphyr*; and Mr. W. W. Watts‖ has made a very careful microscopic study of certain specimens from "Connor, Sandy Braes." Probably, by-the-by, the order of these two names should be reversed. The general aspect of the rocks of Sandy Braes has been touched on recently by Messrs. M'Henry and Watts¶ and by myself.**

The plateau derives its name from the sand produced by the decomposition of the rhyolites, sand of any kind being scarce in this region. The rubbly products

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* It would be unnecessary to point out the origin of this term, had not both Mr. Watts and Mr. Smeeth recently applied it to the minute globules into which the glass becomes divided upon contraction. This is only adding a new element to the confusion which has been imported into petrographical nomenclature. *Perlite* was invented by Beudant—"Voyage en Hongrie" (1822), tome i., p. 329—as a French translation of *perlstein*, and to take the place of Haüy's less obvious word *perlaire*. It is the name of a rock having a particular structure; the globules in that rock might be called "pearls," but certainly not "perlites."

† *Op. cit.*, Trans. Geol. Soc. London, ser. i., vol. iii. (1816), p. 190.

‡ "Report on the Geology of the County of Londonderry, &c." (1843), p. 212.

§ *Op. cit.*, Tscherm. Mitth., Bd. i., p. 418.

‖ "Note on the Occurrence of Perlitic Cracks in Quartz," Quart. Journ. Geol. Soc. London, vol. l. (1894), p. 367.

¶ "Guide to the Coll. of Rocks, &c., Geol. Survey of Ireland" (1895), p. 80.

** "The Volcano of Tardree, County Antrim," Geol. Mag., 1895, p. 305.

of the quarry already described, and the still more broken-down material of the braes themselves, are used for garden-paths in the neighbouring demesnes. The braes above the quarry of fluidal rhyolite, and the Sandy Braes proper, north of the road from Doagh to Connor, are covered some four feet deep in rich yellow soil, which results from the decay of various rhyolites, with a trace of admixture from scattered erratics of basalt. Pebbles and boulders of glassy rhyolite are sifted out of this material by the cottagers, and are thrown in heaps beside the roads. The majority of these consist of black obsidian, commonly perlitic, and enclosing porphyritic crystals of quartz, orthoclase, and plagioclase. Some are so thoroughly traversed by perlitic structure as to appear pale grey, like the typical rocks described by Beudant, the perlites of the Glashütte or Skleno valley. Others have bands of greenish lithoidal matter alternating with the glass, fluidal undulations being also exquisitely displayed; others contain coarse spherulitic aggregations, and have their hollows and cracks filled with massive opal, chalcedony, and agate.* A few are of the brown or black "hornstone" type, in which the glass is almost masked by crystallisation; and these connect the obsidians with lithoidal rhyolites of the type common on the Carnearny braes.

On traversing this moorland of Barnish, and the rough fields cut off from it, a number of small excavations are met with, and in almost all of them the same glassy rhyolites are seen. There is probably a square half-mile (a quarter of a square mile) of obsidian in this locality. In the floor of some of the little pits, this rock can be seen as a continuous mass; the quarrymen are only concerned in removing and sifting the rubbly material of the surface. In the upper four feet or so, the boulders of obsidian lie conspicuously in the yellow sand. In some cases this sand is derived from the decay of the glass itself, which becomes rusty-brown and very friable on its surfaces. The boulders are thus mere cores hitherto spared from decomposition. But at the west end of Sandy Braes there is an extensive section, in which the warm brown rubble surrounding the glassy boulders resembles a lithoidal rhyolite, and has a banded structure. Here the glassy surface-matter of a lava-flow has become broken up into blocks some 20cm. or more across, and has sunk into a lithoidal underlying layer, which has been more readily attacked by decomposition.

Brecciation of the glassy products of rapid cooling, by movements going on in the still viscid layers below, is well known in connexion with modern lava-streams.† In parts of the floor of this shallow quarry, lithoidal rhyolite has been exposed, probably forming the main mass of the flow. It is a pink-red rock, resembling that about to be described from the east end of the Braes. Rhyolite

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* Compare Berger, *op. cit.*, p. 190.

† Compare J. W. Judd, "Contributions to the Study of Volcanos," Geol. Mag., 1875, p. 65. Also G. Cole, "Devitrification of cracked and brecciated Obsidian," Min. Mag., vol. ix. (1891), p. 272.

of the lithoidal type of Carnearny occurs opposite the house which stands at the summit of the Doagh and Connor road; and it crops out also over the broad eastern slope of the brae immediately to the south.

The varieties of glassy rhyolite on Sandy Braes may be best appreciated by the microscopic examination of a few samples. It may be convenient to consider first the more distinctly perlitic types, such as have been studied so carefully by Mr. W. W. Watts.* One of these glasses, which I obtained *in situ* on the north side of Sandy Braes, has become grey through the perfection of its perlitic structure. Under the microscope (Pl. IV., fig. 3), the glass is brown, somewhat contrary to expectation, and has a slight tendency to become pumiceous, the minute bubbles being elongated and marking the direction of flow. The perlitic cracks are of course subsequent to this fluidal structure. Among the porphyritic crystals, by far the most abundant is quartz, rounded and corroded by the glass, but with some traces of its bipyramidal form. Orthoclase is fairly common, but plagioclase seems rare. A decomposed greenish prismatic mineral, resembling some "bastites," is the only ferromagnesian constituent that I have seen under the microscope. It is probably pyroxenic.

The characteristic curvilinear cracks in the quartz—often like circles that have met but failed to intersect—have been described as perlitic by Mr. Watts, and he has drawn the conclusion that perlitic structure, occurring in a now crystalline groundmass, is no proof of the originally glassy condition of the rock. There is often, indeed, a resemblance between the cracked quartz-grains and the poorer areas of the perlitic groundmass; but I cannot agree that the cracks in the quartz are "at least as perfect as those produced by the rapid cooling of Canada balsam." The most beautiful perlitic material with which I am acquainted is the specimen of Canada balsam prepared by Mr. F. Chapman, and figured by him in the Geological Magazine.† In my own slides I find cases where the film of glass next the quartz-grain is far more delicately perlitic than the average groundmass; but the cracks are entirely in the film, and do not enter the enveloped crystal.

It has long been known that perlitic structure occurs subsequently to the fluidal and other primary structures in a cooling lava, and when the rock is practically solid; but I fancy that Mr. Watts underestimates the amount of glass present in lithoidal specimens which contain perlitic structure. He states, on the other hand, that in the lithoidal variety which he selects for description‡ "it is very rare to find anything approaching a perlite," *i.e.* perlitic structure. The perlitic cracks in this specimen occur round and also entering the porphyritic crystals, where differences in expansion and contraction are most marked. Mr. W. F.

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* *Op. cit.*, Quart. Journ. Geol. Soc. London, vol. l., p. 367.

† "On a method of producing Perlitic and Pumiceous Structures in Canada Balsam," Geol. Mag., 1890, p. 79.

‡ *Op. cit.*, p. 373.

Smeeth* has critically examined perlitic structure, with a special view to Mr. Watts' conclusions, and declines to class together the cracks in the matrix and in the quartz, "save on an extremely general basis of classification." He remains "unconvinced that an originally lithoidal groundmass has been found exhibiting of itself perlitic structure." Both Mr. Smeeth and Mr. Watts appear to use the word "lithoidal" in the sense of "minutely holocrystalline." If this is so, I agree fully with Mr. Smeeth's remarks; but it must be remembered that the "lithoidal" rocks of old French writers often contain, as above noted, a good residuum of glass, so that even stony-looking rocks may prove in section to be hemicrystalline and occasionally perlitic.

On Sandy Braes, as usual, the perlitic structure is more and more imperfect in proportion as the rock is more lithoidal, and it is conspicuously absent in those lavas which are nearly or actually holocrystalline. On the other hand, it is only fair to Mr. Watts to state that the curvilinear cracks in quartz occur in their best development in those rocks which are most admirably perlitic. Similar causes have produced the two types of cracks in the crystals and the glass respectively.†

A beautifully fluidal and banded perlite was picked out of the surface-sand in the diggings south of Sandy Braes. In the specimen, the glass consists of alternating purple-grey and opaque cream-coloured bands, the flow round the porphyritic crystals being most effectively seen. In microscopic section, the creamy bands become grey and almost colourless, while the others are a strong yellow-brown (Pl. IV., fig. 4). The almost colourless bands are the more lithoidal, as may be seen between crossed nicols; but they contain at the same time a larger quantity of pure glass, the primitive crystallites having withdrawn themselves to form a multitude of little greenish or colourless prisms, and specks which are probably magnetite. One of these lighter layers is exceptional, the prominent microlites being dark red rods, on which a number of colourless platy crystallites, of high refractive index, lie transfixed. The material in the brown layers is less differentiated within itself, and the colouring matter in the more translucent parts remains unresolved, even on the thin edges of the section and with a power magnifying 400 diameters. In the more dusky of these brown layers, "cumulites," aggregates of globulites, can be distinguished as causing the cloudy effect. Crystallites occur in the brown bands, similar to those in the lighter ones, but more sparsely developed; and in addition there are numerous and remarkable red-brown microlites, in the form of comparatively long rods bent about the middle.

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* A Perlitic Pitchstone from the Tweed River, New South Wales, with remarks on the so-called Perlitic Structure in Quartz," Journ. Roy. Soc. of N.S. Wales, vol. xxviii. (1894), p. 306.

† Since the reading of the present paper, Mr. Watts has published (Geol. Mag., 1896, p. 15) a review of Mr. Smeeth's observations, which does not, I think, affect the remarks that I have made above.

They measure about ·05 mm. from end to end, and resemble geniculated twins. The angle between their components can be measured in a number of examples, those being selected in which the two arms appear parallel to the plane of the section. The average of six measurements yields an angle of 123°, the lowest figure being 114½°, and the highest 130°. It is obvious that, in such small crystals, examples may be selected which are symmetrically disposed, but in which the angle of the twin is towards the observer, and the plane of the arms slightly oblique to that of the section. In such cases the apparent angle will always be larger than the true angle. The angle of the geniculated twins of rutile is 114° 26′, and I do not hesitate to refer these abundant microlites to that mineral. Sometimes a second geniculation occurs in them, opposite in direction to the first, and the resulting crystal is somewhat Z-shaped.

What has become, however, of the titanium oxide in the almost colourless layers of this rock? There can hardly be so striking a chemical differentiation between adjacent bands as to cause all the titanium to accumulate in the brown ones only. We are here in face of the many problems relating to the conditions which promote the growth of mineral species. Probably in the light-coloured layers—with the exception of that already noted, in which red rods actually occur—the segregation of the iron oxides as specks of magnetite has drawn the titanium into natural association with them, a titaniferous iron ore resulting. Had sufficient lime been present, and less iron, sphene might have been produced instead. But now follows a second problem. In what holocrystalline rock does such an abundance of rutile occur as is seen in the brown layers of this lava? What conditions have allowed the titanium to get so clear a start of other chemical constituents? I fear that we must leave the matter here, and return from speculation to the structural details of the rock.

Perlitic structure occurs in both the brown and the lighter bands, and can be best seen in the latter when the light is thrown up obliquely. Mr. Watts* has observed a curious fact in sections of the obsidian of Sandy Braes, which is also well seen in the browner layers of the present banded specimen. The interior of some of the perlitic globules appears distinctly paler than the ground outside them, and occasionally a patch, more or less central, is actually colourless. In one case a globule extends into both a brown and an adjacent almost colourless band, and the clearer patch is even more translucent than the lighter of the two bands. Certainly, as Mr. Watts has remarked, some bleaching seems to have gone on. The same puzzle is likely to crop up in the examination of other perlites; but its explanation proves to be singularly simple. With a high power, the paler areas and their rim of darker glass cannot be brought into focus at the same time; we are looking down into a concavity in the surface of the section, the edges of which

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* *Op. cit.*, Quart. Journ. Geol. Soc. London, vol. l., p. 370.

are often sharp and the sides steep. In the final grinding, a whole hemisphere or smaller portion of a sphere has become pulled away bodily from the perlitic globules, leaving the section thinner, and consequently lighter in colour, beneath the concavity. Of course, cases might be found in which the accident has occurred during the grinding of the lower surface, in which event the edges of the concavity must be found by focussing down on to the slide instead of away from it.

The ordinary blue-black porphyritic obsidian of Sandy Braes is less strikingly perlitic than the two foregoing examples; but the curving cracks can often be brought out, as Mr. Watts has mentioned, by the use of polarised light, anisotropic decomposition-products having separated along them. The purity of the glassy groundmass is due to the formation of minute curving crystallites, only a stage higher than "margarites." These have arisen even in the intrusions of glass which penetrate the porphyritic crystals. Besides the usual quartz-grains, and monoclinic and triclinic felspars, a green pyroxene is an important constituent. It occurs on a bolder scale than in the pitchstone of Carnearny, but its crystals are more injured. It is impossible to measure its angles of extinction in the sections studied, but its pleochroism corresponds to that of a soda-pyroxene approaching ægirine. One crystal has a thin outer zone of a slightly darker colour; the two portions of this zone that lie parallel to the long axis of the crystal become extinguished simultaneously, independently of the behaviour of the central mass; while the terminal portion, seen only at one end, becomes extinguished independently of any of the other areas. The central and principal area does not become dark in any position between crossed nicols, and the section, as shown by the figure in convergent light, is cut nearly perpendicularly to one of the optic axes. This in itself, owing to the phenomenon of conical refraction, would account for the absence of extinction; but the outer zone of another specimen in the same slide behaves similarly. Observations with sodium light, with red light having a wave-length somewhat longer than B in the solar spectrum, and with blue light obtained by using a solution of ammonio-cupric sulphate, show that there is a marked dispersion of the bisectrices; the positions of extinction in the blue light, in the section examined, are 6° removed from those in the red light, and those in sodium-light are intermediate. Since the section is almost perpendicular to an optic axis, it can only be slightly oblique to the optic axial plane; consequently, if we are dealing with inclined dispersion only, this dispersion would prove to be of a very marked character in a section parallel to the clinopinacoid.

Inclined dispersion is, indeed, strong in ægirine and in the soda-augites generally. In the artificial soda-augites, moreover, made by Bäckström,* complete extinction could not be obtained.

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* "Sur la reproduction artificielle de l'aegyrine," Bull. Soc. française de Min., tome xvi. (1893), p. 132.

The specific gravity of the "Pearlstone Porphyry of Sandy Brae" is given by Berger[*] as 2·38. He found 2·52 for the "Pitchstone Porphyry" in its "blue-black vitreous varieties;" nearer the surface, where it became olive green, it had a specific gravity of 2·50, and at the surface it was yellowish green and rather earthy, giving 2·40.

I do not think that many really glassy specimens can be as high as 2·50; my own blue-black obsidians give 2·43, and an altered brownish glass, given me by Mr. A. G. Wilson, is only 2·36.

For comparison with these figures, we may note those given by Prof. Judd[†] for the rhyolites of Lipari, the obsidian having there a specific gravity of 2·37, and the most lithoidal lava rising to 2·53.

Berger states that fragments of the perlite of Sandy Braes intumesce before the blowpipe "to four or five times their first volume, fusing into a foamy and light glass, not unlike pumice-stone." This, as far as I am aware, is the earliest record of this interesting observation, which was afterwards repeated by Beudant[‡] on the glassy rocks of Hungary, and which has been commented on recently by Professor Judd.[§]

As already mentioned, opal and chalcedony form common products of alteration in the rocks of Sandy Braes, as in Hungary, Mexico, and other rhyolitic areas. Vesicular cavities have been partly filled up by banded agates, and sometimes the ground of the rock itself has been converted into chalcedony, while retaining its most intimate structures. In one example of this kind, the glass has become purple-red and flinty, too hard to be scratched by the knife; but under the microscope it shows a multitude of primary "trichites," arranged in a delicate and wavy fluidal structure. Polarised light, however, reveals long fibres of chalcedony, passing through the ground in spherulitic bunches, which abut against the pre-existing cracks of the glass and there terminate. They seem to arise from independent centres, and not from the porphyritic crystals, and represent a structure superimposed during the silification of the matrix. This is one of those numerous cases in which the study of the microscopic section alone might lead to the most erroneous conclusions.

This particular rock is of interest as containing a fair amount of warm brown hornblende, some crystals of which have been bleached and much altered by the action of the groundmass round them. The red colouring-matter of the chalcedony or jasper into which the ground is now converted is distributed in brilliant little patches, resembling hæmatite and affecting polarised light; these have spread

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[*] *Op. cit.*, p. 191.

[†] "Contributions to the Study of Volcanos," Geol. Mag., 1875, p. 62.

[‡] "Voyage en Hongrie" (1822), vol. iii., p. 362.

[§] "The Natural History of Lavas," Geol. Mag., 1888, p. 6.

from cracks and hollows, and probably represent material imported into the rhyolite from outside.

The specimen from which this section was cut contains a mass of brownish and whitish opal and agate at its centre. Cavities occur in the dull agate, and small cubes have at one time developed in them. These are now represented by pure white epimorphs, measuring about ·75 mm. in the side. While the opal of the cavity, mingled, doubtless, with chalcedony, has a specific gravity of from 2·10 to 2·27, the material of the epimorphs is almost uniform, giving 2·26. Under the microscope, it is isotropic, and shows a minutely globular structure like that of "beekite." There is no doubt that it also is chalcedonic or opaline. I can find no trace of the original cubes, which may have consisted of rock-salt or some easily removable substance.

This final deposit of chalcedony corresponds, however, in its opaque whiteness, to that which has spread over the adjacent surface of the opaline mass. In a diffusion-column of exceptionally long range, most of this powdery substance was found to float at the same level as the epimorphs; but, under high powers of the microscope, the material proves to be of complex character. Fibrous patches of chalcedony are seen; and numerous minute crystals, too thin in any direction to affect polarised light, form the finest constituents of the powder. These crystals appear as rectangles, or as parallelograms with the obtuse angle measuring about 100°; their greatest length is about ·0125 mm., so that eight hundred would extend across 1 cm. They are perfect in form for the most part, but have a slight tendency to additional growth at the edges, the rectangular sections then showing little prominences at their angles. On causing the rectangular bodies to roll over in water under the cover-glass, they show obtuse angles on other faces of the prism; the prevalence of squares and rectangles makes me regard the solid form as monoclinic, bounded by the three pairs of pinacoids.

After boiling in a strong solution of caustic potash, and allowing to stand for forty-eight hours, the chalcedonic fibres were almost all dissolved away, and an immense number of the microlites above described were set free from entanglement in them. Examination during the process of destruction of the chalcedony shows that the minute crystals are normally thus hidden away among the fibres.

After boiling in strong hydrochloric acid, and standing for forty-eight hours, the chalcedony showed a tendency to part along its fibres, and many of the microlites became thus set free. They were naturally not so clean and clear as in the sample treated with potash.

I am unwilling to withhold the wider observations on the rhyolites of the county of Antrim until the identity of these interesting little bodies can be proved. They are neither carbonates nor phosphates; probably they are silicates, for they produce a cloudiness in a bead of microcosmic salt.

At the east end of Sandy Braes, the old diggings reveal a beautifully fluidal and banded rhyolite, red and lithoidal, resembling the "millstone-porphyry" of Hungary; it is, however, of somewhat coarser structure, and by no means so vesicular. But its character as a true lava-flow is scarcely open to doubt. Under the microscope it is an unusually handsome rock (Pl. IV., fig. 5), with alternations of burnt-sienna fluidal glass, purplish-grey bands containing embryonic spherulites, and grey-brown lithoidal patches enclosing shattered grains of quartz and felspar. These crystals are often torn to pieces along their curvilinear cracks, and are distributed in angular shreds throughout the groundmass. The specific gravity of this rock is 2·48.

In a digging on the left, as one enters the western excavations at Sandy Braes from the Doagh and Connor road, there is a very friable whitish rock, which absorbs water rapidly, and becomes muddy brown, flecked with black, after any shower of rain. The black specks and patches through it are evidently perlitic obsidian. In places this glassy material can be seen to form a more continuous groundwork, in which the lighter portions lie. Quartz and felspar crystals are porphyritically embedded in the whole.

Examination with the lens, and with the microscope after the manner of Cordier, shows that the lighter portions are pumiceous rhyolite, while the obsidian particles include numerous small spherical vesicles, and are brown by transmitted light. Many fragments of both kinds show doubly refractive effects between crossed nicols, such as are common in pumice, which remains, on cooling, in a state of considerable strain.

Here we seem to have the surface of a rhyolitic lava-flow; but, in the quarry to the north, there is still stronger evidence that we are dealing with the flanks of a volcano. Resting on the pink-red rhyolite already mentioned (p. 95), there is a fragmental rock, containing volcanic material of various kinds. This became exposed during the summer of 1895; it would clearly be desirable to keep a regular watch on the walls of these shifting excavations. The chief component of this agglomerate is a dark grey and almost lithoidal rhyolite, in part retaining the aspect of a perlitic pitchstone, but in part as dull and flinty as a compact Welsh "felsite." Its matrix is harder than the blade of a knife, has a specific gravity of somewhat over 2·50, and contains the usual porphyritic crystals of quartz, orthoclase, and plagioclase. Some of the fragments of this rock are a decimetre in length. It is embedded in a ground which is also dull grey when unaltered, but which contains in addition abundant white fragments of pumice, often 1 cm. in length, and dull angular pieces of other rhyolites. Even the pumice includes quartz grains; and its filaments, examined microscopically, are coated over with minute tridymite. Quartz and felspar crystals, evidently derived from the rhyolites, are scattered through the compact ground of the agglomerate. In fact, when they and the small rock-particles fall out, on the weathered surface of the rock, they leave behind them a mere meshwork, representing the coherent paste of fine volcanic material by which they have been bound together.

Hence I believe that this remarkable rock* gives us a true tuff to add to the products of the Tardree volcano.

The form of rhyolite most common in this tuff is not at present exposed anywhere as a flow, and was probably blown out from some previously consolidated layer. A flinty pebble of it, found in the loose surface-materials on the north side of Sandy Braes, not far from the agglomerate, gives a specific gravity of 2·57, and is practically a very compact eurite. Under the microscope, its density is explained by the microgranular condition of the ground, speckled with an enormous number of very small grains of magnetite, and by the abundance of a blackened and altered biotite, which has suffered from the attack of the molten goundmass, after the manner of the amphiboles in many andesites. This rock is linked to the Selmeczbánya type of rhyolite by the prominence of dark mica, ferromagnesian constituents being decidedly rare in the other lavas of Tardree. Minute but well-formed orthoclase crystals are numerous in the groundmass, which in this respect recalls the rock of Templepatrick churchyard. Larger porphyritic grains of quartz and orthoclase, mostly rounded and corroded, lie scattered among the little ones, and are easily seen by the naked eye. Round these, the microlites of the groundmass have sometimes settled down, forming a thin and delicate granular zone, the elements of which are not in optical continuity with the enveloped crystal. Plagioclase is unusually rare.

Fragments broken from the lithoidal rhyolites of the agglomerate, and examined under high powers of the microscope, are very similar to the pebble above described; they are almost completely crystalline, and a microgranular groundmass, speckled with magnetite dust, is prevalent. Biotite, however, seems somewhat rare.

The relations of the rhyolites of Carnearny, Tardree, and Barnish, and all their outlying spurs, to the basalts which everywhere surround them are, unhappily, of the most obscure character in the field. Berger † expressed uncertainty in the matter, but was inclined to believe that the rhyolites underlie the basalts. Hardman,‡ on insufficient grounds, held that the rhyolites were the older series. Professor Hull, § in the Survey Memoir, placed the rhyolites as older than all the other igneous rocks of the area, and stated that the lower basaltic series, "at Brown Dod, Scolboa, and Carnearny, have remained as isolated patches capping the trachytic rocks." On the next page the Scolboa basalt is

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* Compare "The Volcano of Tardree," Geol. Mag., 1895, p. 306.

† *Op. cit.* (1816), pp. 191, 192.

‡ *Op. cit.* (1871), p. 32.

§ Mem. to Sheets 21, 28 and 29 (1876), p. 9, &c.

described, on the other hand, as protruding through the rhyolite, in the form of an old volcanic neck; and as such it is represented in a very courageous section.[*] The first statement does not prove anything respecting the relative ages of the rocks; but the second, if substantiated, appears convincing. It influenced von Lasaulx,[†] who stated that the rhyolite was, without doubt, the oldest volcanic rock, and who quoted the intrusion at Scolboa as decisive.

Even if the volcanic neck of basalt were an undoubted fact, it might be of upper basaltic age; and the rhyolites might still be intrusive in the Lower Basalts. In the field, however, I can find no warrant for any definite statement as regards Scolboa. The basic rock, on the north side of the farm of Scolboa Upper, is a fresh and handsome dolerite, with porphyritic olivine. It overlies the exposures of rhyolite, without the junction being exposed; and it has a boldly developed columnar structure, even with "tenon-and-mortise" details. These columns stand vertically, as they readily might do in a lava-flow. Otherwise, the nature of the rock might fairly make one regard it as intrusive. Mere inference, however, hardly justifies the section which impressed von Lasaulx; and the patch of basalt is still, I believe, referred to the "lower sheets," *i.e.*, to the lava-flows, in the issues of the Survey map. On Carnearny, the rhyolitic lava-flows dip under the amygdaloidal and fluidal olivine-basalt of the summit; but there is a fair interval of moorland between these rocks, and no junction can be traced.

While Professor Hull,[‡] who admitted that the "actual junction is never seen around Tardree Hill," continued to maintain his view, Mr. G. H. Kinahan [§] stated that the main rhyolite of Tardree was erupted at a later date than some of the basalts, and during the progress of general vulcanicity in Co. Antrim. This must be regarded as a happy suggestion, borne out by subsequent discoveries at Templepatrick. Mr. Kinahan believes, however, that some sporadic eruptions of rhyolite occurred prior to the outpouring of the bedded basalts. Sir A. Geikie,[‖] in 1888, held the whole mass around Tardree to be intrusive, at any rate in the Lower Basalts; but he stated that this view was based solely on analogy with the west of Scotland and Templepatrick. The section accompanying his paper is put forward as showing "what is actually seen"; but the junctions of the two series are firmly drawn on it, and the rhyolite is given the traditional massive character, which is, to my mind, incompatible with its variations in the field. The slight references to "pitchstone and pearlstone" show, however, that the author was prevented from examining the sections at Sandy Braes.

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[*] Mem. to Sheets 21, 28 and 29 (1876), p. 19.

[†] "Aus Irland" (1878), pp. 168 and 169. Also *op. cit.*, Tscherm. Mitth., Bd. i. (1878), p. 411.

[‡] "Phys. Geol. and Geogr. of Ireland," 1st ed. (1878), p. 64; and 2nd ed. (1891), pp. 98 and 99.

[§] "Manual of Geol. of Ireland" (1878), p. 162.

[‖] *Op. cit.*, Trans. Roy. Soc., Edin., vol. xxxv., p. 171.

The traditional and continuous dome of "trachyte-porphyry" appears in force in the longitudinal section of the Geological Survey, sheet 31, published in 1891. It is represented as traversed by basalt dykes, some of which must be regarded as expressions of opinion. There is, it is true, an odd little exposure of crumbling and spheroidal basalt, south of the Doagh road, opposite the western quarries of Sandy Braes. This is probably, from its steeply inclined contact-plane with decomposing rhyolite, a dyke belonging to the upper basaltic series.

To conclude, then, Professor Hull, who regarded the Tardree *massif* as a volcano,* seems to have insisted too little on its complexity, too much upon relationships which are confessedly dubious in the field. Sir A. Geikie was inclined to press too far the analogy with the intrusive "granophyres" of Mull and Skye. On the moorlands themselves, the evidence points to the occurrence of various rhyolitic lava-flows, round about an intrusive neck at Tardree Mountain. Some of these appear to be earlier than the basaltic flows of Carnearny, which are mapped as belonging to the lower series: others appear to be traversed by basalt dykes. But, as yet, material is wanting on which to found even a diagrammatic section.

IV.—Note on Bauxite.

The products of decomposition of certain of the rhyolites, both of the Tardree and Templepatrick types, suggests an affinity with the bauxitic clays and bauxites, which also occur in the county of Antrim. The whole question of the origin of the bauxites is deserving of a special investigation; but I venture to append this note, as a contribution towards their fuller discussion, before leaving the rhyolitic area round Tardree.

In the cutting on the west side of the road, which runs from Scolboa Upper down into Dunany Bog, the lithoidal lava is exposed in a soft form, pale grey, with brown joint-surfaces, and easily cut with a knife. It then yields the shining surface characteristic of a clay. The felspars are dull white and decomposed, and are as sectile as the groundmass. A few grains of bipyramidal quartz occur, as if to prove the identity of the rock. The powder under the microscope shows a groundmass that has lost its structure, with a few orange granules of epidote, and opaque bodies which may be merely magnetite, or which may represent some decayed ferromagnesian constituent. The specific gravity of the groundmass, determined in Sonstadt's solution, is 2·48.

This groundmass adheres to the tongue when touched by it; and its condition,

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* Mem. to Sheets 21, 28 and 29, p. 18, footnote.

together with the white clayey products at Templepatrick, suggests that the rhyolites of Co. Antrim may have had some share in the origin of bauxite.

The famous deposits of les Baux, Bouches-du-Rhône, do not seem to have been traced to any igneous source. They are interstratified with Lower Cretaceous beds, and also with limestones of the Danian stage, and were regarded by M. H. Coquand* as formed by the deposits of mineral springs opening into lakes. They are often of a strong red-brown colour, and are sometimes as pisolitic as the lake-iron-ore which is associated with them. Of course, the aluminium hydrates, none the less, may have been brought down in the form of fine mud by rivers, which flowed over some igneous area. But the bauxites of the county of Antrim are more comparable in their mode of occurrence to those of the Vogelsgebirge in Germany, which are distinctly associated with volcanic débris. Near Giessen, the weathering of a basalt has produced a bauxite with only 4·6 to 10 per cent. of silica, and about 50 per cent. of alumina. The minerals of the original basalt, and the structure of the rock, are still distinctly recognisable.† Further south, near Hanau, a basalt has been described by Petersen‡ as giving rise to a bauxite and a bauxitic clay; these products similarly retain structures and crystals that prove their igneous origin.

Mr. G. H. Kinahan§ has suggested the derivation of the bauxitic clays of the county of Antrim from lithomarge bleached by the action of peat above it; but this does not explain how the aluminium silicates of what is known as lithomarge could become converted into aluminium hydrates. The association of bauxite in Ireland with pisolitic iron-ore suggests that various decomposition-products of basalt have accumulated successively in lakes. This may be true of the Ballintoy area‖; but the section at the Libbert Mine, Glenarm,¶ points to the underlying rhyolitic conglomerate as directly connected with the bauxite. A specimen of this conglomerate is in the collections of the Royal College of Science for Ireland, and Mr. M'Henry has kindly given me, for comparison, a sample of the Glenarm bauxite. The pebbles and felspathic ground in the former rock have decomposed to a white sectile clay, similar, except in colour, to the product at Scolboa. The specific gravity of the white ground, determined in methylene iodide, is 2·44, that of the bauxite of Glenarm being about 2·42. The bauxite of Wochein in

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* "Sur les Bauxites de la chaîne des Alpines (Bouche du Rhône) et leur âge géologique," Bull. Soc. géol. de France, 2me. sér., tome xxviii. (1871), p. 111.

† Will and Lang, quoted by Roth, "Allgemeine u. chem. Geologie," Band ii. (1885), p. 341.

‡ "Uber den Anamesit von Rüdigheim und dessen bauxitische Zersetzungsproducte," Abstract in Neues Jahrb. für Min., &c., 1894, Bd. i., p. 460.

§ "Notes on some of the Irish crystalline Iron Ores," Journ. Roy. Geol. Soc. Ireland, vol. vi. (1886), p. 307.

‖ Mem. to Sheets 7 and 8, Geol. Surv. Ireland, p. 24.

¶ M'Henry, "Age of the Trachytic Rocks of Antrim," Geol. Mag., 1895, p. 263.

Styria is quoted as 2·55; and that of a sample (lithomarge?) from the Ballymena area, given me by Mr. Rigby, varies from 2·40 to 2·60, although the rock is apparently of uniform texture and is iron-stained on its joints only. A red bauxite from Brignoles, Var, gives a result as high as 2·63.

Since the commercial bauxites are a mixed group of materials, from an aluminium iron hydrate, bauxite proper, to aluminous iron ores and bauxitic clays, their specific gravity must obviously vary greatly. Their geological history is still obscure in the county of Antrim. I have carefully washed the sample from the Libbert mine, in the hope of finding crystals or residues from the rhyolites; but the only reward has been the discovery of decayed and pinkish flints. These small fragments can be cut with a knife, like those in some of the Surrey gravel-pits; but their form and structure hint at their true nature. I prepared sections of two of them, which confirmed the idea that they were truly flint; and Mr. A. Vaughan Jennings, to whom the unnamed sections were submitted, referred them to the same substance. These flint fragments are characteristically reddened, and hence a portion of the altered gravel must have become exposed by the denudation of the Lower Basalts before the deposition of the bauxite. It seems possible that the latter rock, in its slightly ferruginous varieties, is derived from the direct accumulation of fine rhyolitic ash—or, as Mr. Symes suggested, from volcanic mud-flows, which carried the material from the flanks of the cones into the lowlands.*

The complete disintegration of the lower surface of the rhyolite at Templepatrick points in the same direction as the rock of Scolboa, which may be called, in old-fashioned style, a "claystone-rhyolite;" and further deposits of bauxite may well lie concealed in the hollows round the *massif* of Tardree. Against this must be set the chemical difficulty of the production of aluminium hydrate, rather than kaolin, in rocks where the latter is the ordinary decomposition-product; but it may be remembered that a compound of aluminium is precipitated from any aluminium salts which may be in solution by the action of carbonates of the alkalies, and that these carbonates are extensively produced during the decomposition of granites, rhyolites, and kindred rocks.

The nature of the precipitate artificially obtained by this reaction is still obscure. Formerly it was supposed to be a simple hydrate; but Muspratt,† using a solution of alum and ammonium carbonate, assigned it the formula $3\,Al_2O_3 . 2\,CO_2 + 16\,H_2O$. Jas. Barratt,‡ working in Muspratt's laboratory, and using aluminium chloride and sodium carbonate, declared that the product, finally washed and dried, was "hydrate of alumina perfectly free from carbonic acid."

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* See Memoir to Sheet 20, Geol. Surv. Ireland (1886), pp. 12 and 16. Analyses on p. 28.

† "On the Carbonate of Alumina," Quart. Journ. Chem. Soc. London, vol. ii. (1850), p. 216.

‡ *Ibid.*, vol. xiii. (1861), p. 190.

Th. Parkmann* discussed the history of the subject, and concluded that there is a carbonate with the formula $Al_2O_3 \, . \, CO_2$, and that "the precipitate produced by the alkaline carbonates in solutions of alumina consists chiefly of this normal carbonate, generally mixed, however, with more or less of a more basic salt or hydrate of alumina." MM. Urbain and Renoul † seem recently to have gone to the bottom of the matter, using alum and sodium carbonate, and also aluminium sulphate and ammonium carbonate. They conclude that the precipitate is a hydrated basic aluminium carbonate, equivalent to $2\,Al_2O_3 \, . \, CO_2 \, . \, 8\,H_2O$; but carbon dioxide is given off from it at 30° C, and the material is "un composé d'une grande instabilité." Messrs. Morley and Muir, in their edition of Watts' Dictionary of Chemistry,‡ still consider aluminium carbonate as of doubtful existence.

MM. Urbain and Renoul's unstable compound, exposed to slow natural agencies, might possibly break up, leaving aluminium hydrate, without such increase of temperature as was found necessary in the laboratory. But this increase is well within the range of climatic variations in Ireland; and, all things considered, it is doubtful if any original basic carbonate could possibly have survived from the Eocene period to the present time. The process, as we may imagine it, is as follows:—Acid vapours attack the lavas in the early stages of their decay, forming soluble combinations of aluminium; secondly, sodium and potassium carbonates flow, in normal volcanic waters, over the deposited products (alums, &c.) resulting from the first attack; thirdly, the hydrated basic aluminium carbonate thus formed is broken up again, losing carbon dioxide and some water, and leaving aluminium hydrate, combined with a portion of the iron oxide that has also undergone hydration.

I do not picture this process as occurring in nature in large masses of aluminium salts. Round about volcanic vents, the products of solfataric action—sulphur itself, for instance—may be found delicately permeating the whole groundmass of a lava, or all the interstices of an ash. From such deposits, hydrated aluminium carbonate might similarly be produced, resulting in aluminium hydrate in a finely divided state, mingled with the more normal products of the decomposing igneous mass. Processes of denudation, in carrying off the finer materials, will wash down the aluminium hydrate, or the aluminium iron hydrate, and will spread it out in some lake or hollow, with an admixture of clay, and perhaps of crystals, from the original rock. While the ready decomposition of basic rocks makes us regard them as the more probable sources of bauxite, we may

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* "On the Carbonates of Alumina, Glucina," &c., Am. Journ. of Sci., ser. 2, vol. xxxiv. (1862), p. 326.

† "Sur une combinaison de l'alumine avec l'acide carbonique," Comptes rendus, vol. lxxxviii. (1879), p. 1133.

‡ Vol. i. (1888), p. 696.

remember that the proportion of alumina present does not vary greatly through the whole igneous series; and the lithoidal rhyolites of the Tardree area, with their uniform, soft, clayey decomposition-products, seem especially calculated to give rise to the pale varieties of bauxitic clay in the county of Antrim. I may add that the decomposing rhyolite of Scolboa yields a considerable proportion of its alumina after mere boiling with sulphuric acid, showing that products soluble in this acid have already arisen within it. Neither the original alkali-felspars nor kaolin would give such a result. A similar but less marked reaction is obtainable from the altered rhyolite of Templepatrick.

V.—ESLERSTOWN.

This is the "Esterstown," and "Esterston" of the Survey Memoir to Sheet 20 (pp. 10 and 11), and lies two miles north-east of Kells and Connor. I must confess that I have not personally visited this exposure. Its apparent area has been much reduced on the latest issues of the geological map, the northern two-thirds of it being now represented as Upper Basalts; and Mr. M'Henry informs me that the pisolitic iron ore which lies below these basalts can here be seen coming in above the rhyolite. Meanwhile the "actual contact with the surrounding rocks cannot be seen," [*] a statement that hardly justifies the section immediately following it upon p. 11 of the Memoir. Here the rhyolite is represented as a magnificent dome, against which the basalts and iron-ore abut. It was probably this section that caused Sir A. Geikie [†] to remark that one of the Antrim rhyolites, south-east of Ballymena, appeared to cross into the Upper Basalts. Similar features are shown in the longitudinal section, sheet 31, with the addition of a dyke of basalt, cutting the rhyolite at a point to which no surveyor is likely to have had access. The rhyolite is described as "a disintegrated porphry," similar to the main type at Tardree; and it may fairly occur as a local intrusive neck or laccolite. But its relations to the Lower Basalts are confessedly not proven, and there is no reason to regard it as so important a mass as is shown upon the published sections.

VI.—KIRKINRIOLA.

The exposure of rhyolite is here very obscure, and was originally noticed by Mr. W. J. Knowles of Ballymena.[‡] It occurs round about the ancient churchyard of Kirkinriola, on the slope of Berk Hill, and the rock has been at some time laid

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[*] Mem. to Sheet 20, p. 10.

[†] *Op. cit.*, Trans. Roy. Soc., Edin., vol. xxxv., p. 171.

[‡] Mem. to Sheet 20, Geol. Surv. Ireland, p. 10.

bare by the action of a little stream, which has here cut through the basalt flows. At present only a few blocks can be found in the stream-bank, and these are not obviously *in situ*: but their characters distinguish them from the other rhyolites to the north and the south-east. The rock of Kirkinriola is a pale-bluish grey rhyolite, of the genuine "trachytic" texture, minutely scoriaceous, and with porphyritic crystals of quartz and orthoclase. The microscope reveals a fair amount of darkened biotite; the quartz proves to be unusually idiomorphic; and a delicate fluidal structure, only faintly seen in the field, is brought out by polarised light. The groundmass is lithoidal, and resembles that of the Tardree rock; but a number of minute pale brown-green wisps of mica are associated with the colourless rods. A microgranular structure appears between crossed nicols, independently of the orientation of the original crystallites; the granules are about ·025 mm. in diameter, and are best studied on the thinnest edges of the section. Here it appears that they are merely flaky crystals of quartz and felspar, hidden away amid the mass of crystallites in the thickness of the slice; the crystallites themselves, which mask their outlines in the body of the slide, are exceptionally minute and ill defined.

It may be remembered that we were tempted to a different conclusion in accounting for the granulation in the rhyolite of Tardree. In such cases it is exceedingly difficult to ascertain whether a granule includes or is surrounded by a given group of crystallites. Where, however, the whole of a groundmass rich in crystallites appears as a mosaic between crossed nicols, it seems fair to conclude that the granules represent the final product of crystallisation, the settling down of what was for a time residual glass. Such does not appear to be the case at Kirkinriola.

No conclusions can be drawn from the present exposures in the field as to the relations of the Kirkinriola rock to the adjacent basalts.

VII.—BALLYCLOUGHAN.

At Ballycloughan, translated as "Quarrytown" on the Ordnance Map, in a fork between the roads from Broughshane and Ballymena, there is a little hill, on the crest of which rhyolite is exposed. A good quarry was worked here in former times for window-sills, &c.;* but there are now several respectable larch-trees growing in its floor. An old man whom I met remembered working in it, and told me, as one often hears in the county of Antrim, that coal had been obtained from it and burnt. Mr. Wm. Gray, F.G.S., has cleared up the mystery in this case; he tells me that a futile boring was put down near this spot by Scotch engineers in

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* Berger, *op. cit.*, Trans. Geol. Soc. London, vol. iii. (1816), p. 191.

1873, the rhyolite having been mistaken for Carboniferous sandstone. Berger had correctly appreciated the rock sixty years before; he observed that it adhered slightly to the tongue, that it contained smoky quartz, lamellar felspar, and brown mica, and that its specific gravity was 2·43. My own specimens, however, give 2·50; the rock, while less crystalline than that of Tardree, has its gravity increased by the abundance of ferromagnesian material.

The geological surveyors* noted the occurrence of a vertical flow-structure, which can be distinctly seen in the quarry. The rock is of a cool grey colour; it is not scoriaceous, but is somewhat powdery and trachytic in texture.

Under the microscope, its groundmass resembles that of the rhyolite of Templepatrick churchyard; but biotite is unusually abundant. Cumulites are well seen in the glass, and minute felspathic prisms of the Templepatrick type, many of them simply twinned, occur freely, imparting a granular effect here and there between crossed nicols. Porphyritic crystals are scarce, but biotite occurs among them. One of the quartz grains has been restored to something of its former outlines by the growth of a broad micropegmatitic zone around it, in which quartz finally predominated.

In the Survey Memoir, the dark mineral is regarded as probably hornblende; but the description given of its microscopic characters (p. 22), and examination of the rock itself, would lead to a different conclusion.

The vertical position of the flow-planes at Ballycloughan is certainly a good piece of evidence for regarding the rhyolite as occupying a volcanic neck. Mr. G. H. Kinahan† has affirmed that the rhyolites of this area are intrusive in the basalts, and has placed them as contemporaneous with the rock of Templepatrick. Sir A. Geikie‡ has stated that they occur as "intrusive bosses, sheets, or veins." I suspect that any lava-flows which may have been poured out from these centres were worn away during the long interval when the Lower Basalts were being denuded—an interval that was marked by the production of iron-ores, bauxites, and ferruginous clays in Co. Antrim. The rhyolitic conglomerates of Ballypalady and Glenarm occur characteristically on this horizon.

VIII.—CLOUGHWATER.

We now reach the most northerly, and perhaps the most remarkable exposure of lithoidal rhyolite. Between Cloughwater School and the main road from Ballymena to Cushendall, near the spot marked "Meeting Ho." on the Ordnance map, there lies a little hollow of bogland, draining northward into the Clough River. Looking south, against the semicircle of dark basalt hills, with the huge

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* Mem. to Sheet 20, pp. 11 and 22.

† "Manual of Geol. of Ireland," p. 162.

‡ *Op. cit.*, Trans. Roy. Soc., Edin., vol. xxxv., p. 171.

neck of Sliemish towering in the distance, the eye is caught by a strange white boss in the midst of the bog, utterly at variance with its surroundings. Its form reminds one of the "quartz-knobs" of some metamorphosed areas. This little protrusion is composed of the most beautifully fluidal rhyolite, the flow-planes being again vertical and running right across the boss. The whole mass is so small that it might possibly be a displaced portion of a lava-stream; as it stands, we must regard it as representing a volcanic neck. The geological surveyors* report aptly that the laminæ in the field "remind one of the structure of slate or shale."

This delicately banded and fluidal lava is here grey, here pinkish, here faintly yellow brown. In part it has been brecciated, or has picked up dull grey angular fragments of another rhyolite. The flow-bands, visible with the naked eye, are often alternately pink-brown and pale-grey, and fifty may occur within a centimetre. Here and there a few vesicles occur, greatly flattened out between two adjacent bands; in some of these, crusts of hyalite have arisen.

Some of the bands are seen to consist of small spherulites, and minute granules of quartz glisten throughout the mass. The only porphyritic crystals observed are rare flakes of biotite, one of which is 5 mm. across.

The specific gravity of this rock varies more than might be expected, and it is probably more glassy in some layers than in others. The results obtained from various specimens range from 2·40 to 2·49.

Mr. A. Percy Hoskins, F.I.C., F.C.S., of Belfast has very kindly made a quantitative analysis of one of the compactest specimens. The work was done under considerable disadvantages, including the proximity of building-operations; but Mr. Hoskins informs me that the excess in the analysis is likely to lie mainly in the lime. The important results for the silica, the joint alumina and iron oxide, and the alkalies, have been satisfactorily checked.

BANDED RHYOLITE OF CLOUGHWATER, CO. ANTRIM.

Analysis by A. P. Hoskins, F.I.C., F.C.S.

Silica	75·97
Alumina	15·29
Ferric Oxide	2·54
Lime	1·15
Magnesia	0·24
Potash	3·89
Soda	2·86
Loss on ignition . . .	0·57
	102·51

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* Mem. to Sheet 20, p. 11.

The rock is thus a close ally of that of Tardree, analysed by Mr. Player, and differs mainly in having a somewhat higher proportion of soda.

Two types of this rhyolite have been examined microscopically. One shows bands made up of minute brownish spherulites, through which the flow-structure runs; while, alternating with them, are broader bands in which the spherulites are not so clearly arranged, but lie scattered in a more dusky glass crowded with globulites. With a high power, a delicate radial structure can be seen in the spherulites. Among the microlites and crystallites, there are crowds of red rods, occasionally forming geniculated crystals, like the minute rutiles of Sandy Braes. Such quartz crystals as can be identified occur in the more dusky bands, and one ·25 mm. long is quite a giant among them.

The second specimen is still more delicately banded (Pl. IV., fig. 6), and includes some dull elongated flakes of another kind of rhyolite. Quartz, and not tridymite, seems to have crystallised out along the hollows. The whole rock shows minute radial spherulites under a high power, and rods of rutile occur everywhere, lying for the most part parallel to the delicate flow-structure. They are thus, as at Sandy Braes, connected with the primary processes of crystallisation in the rock.

Biotite is the only recognisable ferromagnesian constituent, and occurs minutely in the spherulitic ground, with granules of quartz and flakes of felspar. But, as a whole, the rock is composed of crystallites, not crystals, and it is this extreme delicacy of structure which has enabled it to show the phenomena of flow so perfectly.

The parallelism of the flow-planes across the exposed boss in the middle of the bog may indicate that the vent was in this case a short vertical fissure. It would be well to watch the progress of excavations in the adjoining peat, on the chance of some junction of rhyolite and basalt being eventually revealed.

IX.—Conclusion.

In concluding this detailed examination of the rhyolites of the county of Antrim, I may perhaps be allowed to say how attractive this quest has been for me, ever since Mr. W. J. Knowles of Ballymena sent a fragment of perlite from Sandy Braes to Prof. Judd's laboratory some fifteen years ago. In 1891 I first crossed the Tardree area, inspired by the fine series of specimens collected by Mr. M'Henry for the Geological Survey. In 1892, Mr. G. W. Butler and myself visited Hungary, in order to become acquainted with the rhyolites of a classical area on a bold and open scale. This journey only rendered more apparent the variety and beauty of the products of the volcano of Tardree. In the foregoing paper I have endeavoured to make some contribution towards our knowledge of them. Observations in the field, aided by the lens, have been of primary importance; in the laboratory, the tridimensional methods of the older workers have proved of constant service; and the diffusion-column, devised by Prof. Sollas, has often reduced a task of considerable labour to one both of delicacy and pleasure.

It will have been seen that the rhyolites of the county of Antrim are as a rule poor in ferromagnesian constituents, but that the occurrence of these minerals divides the rocks into two groups, the biotite-rhyolites, such as those of Templepatrick, Kirkinriola, and Ballycloughan, and the augite-rhyolites, represented on Carnearny and Sandy Braes. All the types, whatever their structure, are fairly rich in porphyritic constituents, with the exception of the fluidal rhyolite of Cloughwater.

The banded, fluidal, and perlitic structures in these rhyolites are probably unsurpassed by those of any other lavas in the British Isles; but spherulitic structure is certainly uncommon.

The various glassy and fluidal lavas round about the dome of Tardree Mountain probably flowed from that centre, and at one time built up a true volcanic cone around it.

This view is strengthened by the occurrence of a volcanic agglomerate on Sandy Braes.

The only section in which evidence as to the sequence in time and actual relations of the rhyolites and the plateau-basalts can be obtained is the western part of the quarry at Templepatrick. Here the rhyolite is intrusive between a mass of basalt and the chalk, along the line of the flint-gravels, and it includes, somewhat obscurely, a lump of basalt near its upper margin. The conglomerates of Glenarm and Ballypalady, with pebbles of rhyolite, occurring between the Lower and the Upper Basalts, merely prove that the rhyolites were intruded or extruded prior to the formation of the Upper Basalts; they prove nothing regarding the relations of the rhyolites and the Lower Basalts, unless it can be shown that they are tuffs and not ordinary conglomerates.

From the relations of the bauxite of Glenarm to the underlying rhyolitic conglomerate, and from the general type of decomposition of the lithoidal rhyolites, it is suggested that the pale bauxites may have originated in the alteration of rhyolites or rhyolitic ashes.

Finally, I must express my thanks to those active members of the Belfast Naturalists' Field Club who have so generously helped me in the field or with photographs of the sections visited:—Miss M. K. Andrews, Mr. W. J. Fennell, Mr. Wm. Gray, M.R.I.A., Miss S. M. Thompson, and Mr. R. Welch. I am specially indebted to Mr. A. M'Henry, M.R.I.A., of the Geological Survey of Ireland; to Mr. J. St. J. Phillips, A.R.I.B.A., of Belfast, for permission to reproduce two of his admirable photographs; to Mr. A. P. Hoskins, F.I.C., for his quantitative chemical work; to Mr. T. D. La Touche, of the Geological Survey of India, who helped me, during his stay in Dublin, in the delicate observations with the diffusion-column; and to my Wife, for determining the specific gravity of the typical specimens, and for the microscopic drawings which accompany the present paper.

EXPLANATION OF PLATE III.

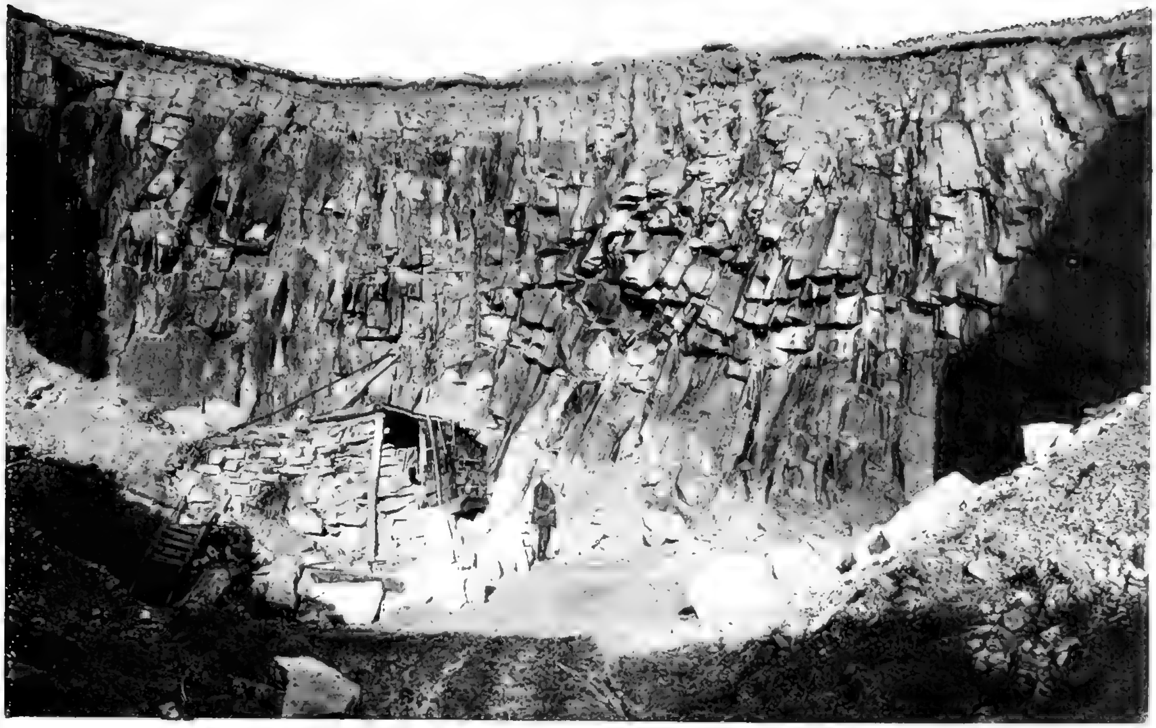
PLATE III.

Figure

1. Lithoidal Rhyolite, southern quarry, Tardree Mountain, showing characteristic **jointing. Photographed by Mr. J. St. John Phillips.**

2. Banded lithoidal Rhyolite, quarry on ascent from Tardree Inn to Sandy Braes. **Photographed by** Mr. J. St. John Phillips.

Fig. 1.



J. St. J. Phillips, phot.

Fig. 2.

J. St. J. Phillips, phot.

RHYOLITES OF CO. ANTRIM.

EXPLANATION OF PLATE IV.

PLATE IV.

MICROSCOPIC SECTIONS OF RHYOLITES OF THE COUNTY OF ANTRIM.

Figure

1. Lithoidal Rhyolite, from a column in northern quarry, Tardree Mountain, with minute cavities containing tridymite. × 10.

2. Perlitic and spherulitic glassy Rhyolite, hollow east of Carnearny. Soda-augite is abundant. A spherulite is seen in the upper part of the drawing. × 10.

3. Perlitic Rhyolite-glass (Obsidian), from mass *in situ*, north side of Sandy Braes. A slight fluidal structure is perceptible. × 14.

4. Fluidal, banded, and perlitic glassy Rhyolite (Pitchstone), from a boulder on south side of Sandy Braes. × 11.

5. Fluidal and banded lithoidal Rhyolite, east end of Sandy Braes. The brecciation of the porphyritic crystals of quartz during the flow of the mass is well seen. × 10.

6. Fluidal and delicately banded lithoidal Rhyolite, Cloughwater, N. of Ballymena. Porphyritic crystals are almost absent from this rock. × 7.

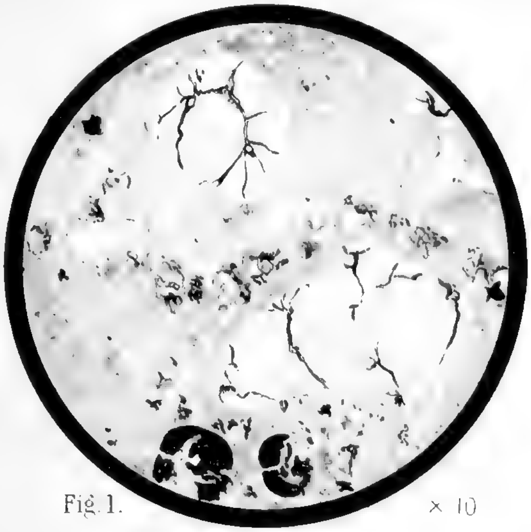


Fig. 1. × 10

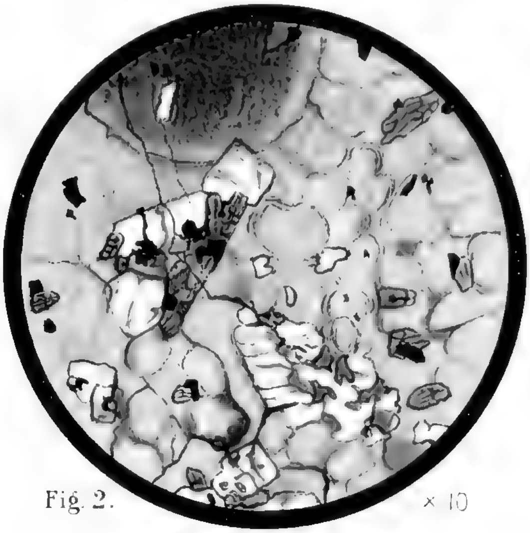


Fig. 2. × 10

Fig. 3. × 14

Fig. 4. × 11

Fig. 5. × 10

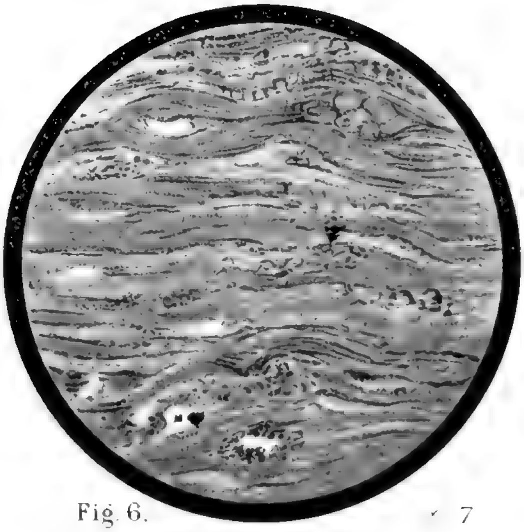


Fig. 6. × 7

B Cole del.

M'Farlane & Erskine Lith. Edin.

RHYOLITES OF Co. ANTRIM

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By THOMAS PRESTON, M.A., F.R.U.I.

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ON THE CONTINUITY OF ISOTHERMAL TRANSFORMATION FROM THE LIQUID TO THE GASEOUS STATE.

By THOMAS PRESTON, M.A., F.R.U.I.

[Read February 19, 1896.]

When any substance passes from the liquid to the gaseous state by isothermal transformation, the relation between pressure and volume is represented diagramatically by a curve such as that shown in fig. 1. In this curve, the part A B refers to the condition of the substance in which it is altogether liquid, and along this part the volume alters only slightly as the pressure is varied. When the pressure is gradually reduced, however (the temperature being maintained constant), a point B is reached at which the liquid begins to boil, and the whole mass may be transformed into the gaseous state under constant pressure, if heat be supplied to keep the temperature constant while the volume is allowed to increase from B to D. The part B D of the isothermal is consequently a right line parallel to the axis of volume, and at D the whole mass is in the condition of saturated vapour. Beyond D the curve D E is approximately a rectangular hyperbola as it represents the isothermal of a gaseous substance which approximately obeys Boyle's law.

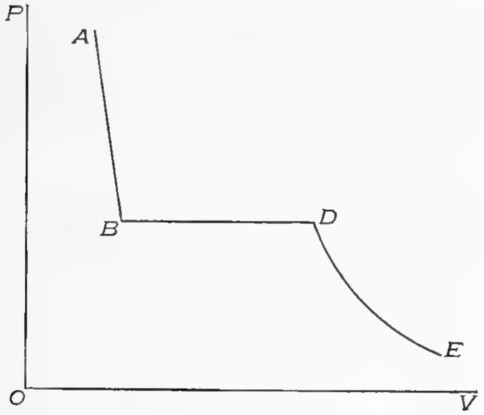

Fig. 1.

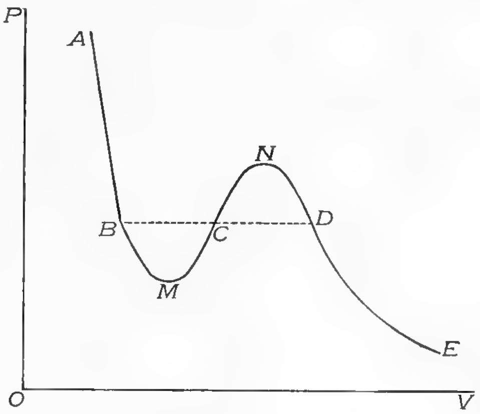

Fig. 2.

Very shortly after Andrews' celebrated experiments on the isothermals of carbon dioxide, and on the continuous transformation of matter from the gaseous to the liquid state, Professor James Thomson, in an ingenious speculation (suggested by the shape of the isothermals immediately above the critical temperature), proposed an isothermal curve of the form represented in fig. 2, which embraces the idea of continuity of transformation, so much insisted on by Andrews. Here, in passing from B to D, the substance is supposed to be homogeneous throughout, and not to be partly liquid and partly vapour as in the corresponding part B D of the isothermal of fig. 1. The word homogeneous must here, however, be taken with some reservation, for although the mass, as a whole, may be apparently homogeneous—that is, one cubic centimetre may be on the whole the same as another,—yet when considered in very small portions, the mass may be intensely heterogeneous. For example, small portions may approach the gaseous state more nearly than the liquid, while others may be more decidedly in the liquid condition.*

Since the time of Andrews and Thomson, various attempts have been made to deduce from dynamical principles a general relation connecting the volume, pressure, and temperature of a substance which will apply to the liquid as well as the gaseous condition of matter, and which will also hold throughout the transformation from one state to the other. Of these, the most notable examples are those of Van der Waals and Clausius, both of whom obtained equations (founded on certain assumptions), for the isothermal curves which, when traced, presented the characteristics of the curve suggested by James Thomson, as shown in fig. 2.

A difficulty which presents itself at once to the acceptance of such a curve as representing a realisable series of transformations, is that the part M N represents conditions of the substance in which the volume and the pressure increase together. As a consequence, this part of the curve has been generally regarded as unrealisable, and direct experimental evidence of it has been nowhere found in nature; yet, the interesting phenomena of superheating and supersaturation are so well represented by the portions B M and D N, that the whole curve has been admitted as a possible, if not a necessary, generalisation.

It is to this unrealisable part of the curve that I now wish to attract attention, and I shall endeavour to show that there is a conceivable condition of the substance which satisfies the extraordinary demands of the portion M N, viz., that the pressure and volume shall increase together, and that throughout the transformation the substance shall be in equilibrium, although necessarily unstable.

For this purpose, let us consider the condition of the substance at any point of the isothermal between B and D. What really happens in practice is, that

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* This view has been put forward more than once in the Author's *Theory of Heat*, *e.g.*, p. 396.

bubbles of vapour are formed in the interior of the liquid mass, and by reason of the action of gravity these rise vertically upwards, and the result is, that the mass becomes separated into two portions, the upper part of the containing vessel being filled with vapour, and the lower part by the remaining liquid. The action of gravity is thus to separate the vapour bubbles from the liquid, and it is on this account, as we shall see, that the part B D of the isothermal is, in practice, a right line as shown in fig. 1. If, however, we imagine the action of gravity to be removed, then a bubble of vapour when formed would remain *in situ*, except in so far as it might drift with currents in the mass. The formation of bubbles, under these conditions, would cause the mass to swell into a spongy condition—a heterogeneous mixture of liquid and vapour,—in which, if the equilibrium could be maintained, the volume and pressure would vary according to laws very different from the simple law of constant pressure which governs the transformation of ordinary boiling, under the action of gravity (fig. 1).

In order to determine, under these conditions, how the pressure varies with the volume, at constant temperature, let us consider the case of a mass of liquid in which a spherical bubble of the vapour of the liquid has been formed, as shown in fig. 3. For the sake of clearness, let the mass be enclosed in a cylinder by means of a piston, so that the volume and external pressure can be varied at pleasure, then, if p be the pressure, applied through the piston (which we may term the external pressure of the mass, in the ordinary sense), the pressure at any point in the interior of the liquid will be $p + c$, where c is a quantity depending on the surface film, and, as it arises from the mutual attraction of molecules well within each others sphere of action, may be very large. But, if ϖ be the vapour pressure within the bubble, the relation connecting p and ϖ is

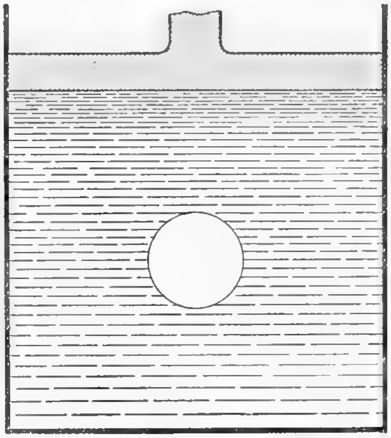

FIG. 3.

$$\varpi = p + \frac{2T}{r}, \qquad (1)$$

where r is the radius of the bubble, and T the surface tension of the surface film separating the liquid and vapour. It is clear, therefore, that if ϖ remains sensibly constant, p must increase as r increases, or in other words, the external pressure and the volume must increase simultaneously, if equilibrium is to be maintained.

The saturated vapour pressure ϖ, however, is not quite constant, but varies at constant temperature with the curvature of the film with which it is in contact, and if ϖ_0 be taken to represent the normal saturated vapour pressure, that is the pressure of a saturated vapour in contact with a plane surface of its own liquid, then the saturated vapour pressure in contact with a concave spherical surface, of radius r, is easily shown to be

$$\varpi = \varpi_0 - \frac{2T}{r} \cdot \frac{\rho_2}{\rho_1 - \rho_2},$$

where ρ_1 is the density of the liquid, and ρ_2 the density of the saturated vapour. Hence, the relation (1) connecting p and r becomes

$$\varpi_0 = p + \frac{2T}{r} \cdot \frac{\rho_1}{\rho_1 - \rho_2}. \tag{2}$$

In this equation, all the quantities other than p and r may be taken as remaining constant during an isothermal transformation, and consequently, within certain limits, the volume and external pressure of the mass should increase together.

This equation, however, cannot be expected to hold in the extreme case, in which the bubble is so small that the mass within it ceases to possess distinctly the properties of a vapour, or to the other extreme case, in which the bubbles become so large and numerous that the remaining liquid, by reason of being drawn out into thin films, or otherwise, ceases to behave as a liquid in regard to the transmission of hydrostatic pressure, etc. Within certain limits, however, equation (2) gives the relation between the external pressure and the volume of the mass.

Thus, in the case of a single bubble, if the whole mass be taken as unity, and the mass of vapour within the bubble be m, then the mass of the liquid portion will be $1 - m$, and the whole volume will be

$$v = \frac{m}{\rho_2} + \frac{1 - m}{\rho_1}. \tag{3}$$

But, if the radius of the bubble be r, we have

$$m = \frac{4}{3}\pi \rho_2 r^3; \tag{4}$$

consequently, equation (3) becomes

$$v = \frac{4}{3}\pi \rho_2 r^3 \left(\frac{1}{\rho_2} - \frac{1}{\rho_1}\right) + \frac{1}{\rho_1}; \tag{5}$$

or, denoting the specific volumes of the liquid and vapour by v_1 and v_2, we have, from equation (5),

$$v - v_1 = \frac{4}{3}\pi r^3 \left(1 - \frac{v_1}{v_2}\right). \tag{6}$$

Now, equation (2) gives

$$r = \frac{2T}{\varpi_0 - p} \cdot \frac{v_2}{v_2 - v_1}. \tag{7}$$

Therefore, (6) becomes

$$(v - v_1)(\varpi_0 - p)^3 = \frac{32}{3} \cdot \pi T^3 \left(\frac{v_2}{v_2 - v_1}\right)^2. \tag{8}$$

Consequently, since the right hand member of this equation remains constant, the equation of the isothermal curve assumes the hyperbolic form

$$(v - v_1)(\varpi_0 - p)^3 = \text{constant}. \tag{9}$$

This equation holds for a spherical bubble of vapour surrounded by its own liquid, and in this case it is to be noted, that p must always be less than ϖ_0, or the external pressure of the mass must be less than the normal saturated vapour pressure, and this is what is indicated by the portion M C of the isothermal, lying below the right line B D in fig. 2.

So far, we have considered the case of a single bubble, surrounded by its own liquid, but the foregoing reasoning will apply when a number of equal bubbles are formed. If the bubbles are of different sizes, however, the capillary pressures, arising from the curvatures of their surface films, will be different, and equilibrium will be impossible—the larger bubbles tending to expand, and the smaller to collapse.

It would appear, therefore, that the mass might be gradually transformed from the liquid to the gaseous condition, by allowing a system of equal bubbles to gradually increase in size while the volume increased to v_2 and the external pressure to ϖ_0, and this value would be reached if the bubbles could be supposed to increase gradually till the whole mass reached the state of vapour. Long before this final condition can be reached, however, the liquid portions of the mass, which interlace the bubbles and fill the spaces between them, would be drawn out into thin films, and the conditions would be such, that the foregoing reasoning could not be applied. The action of the distended surface film, in fact, will be such as to draw the liquid parts, which fill the spaces between the bubbles, into spherical drops, so that a stage is ultimately reached in which the mass consists of a system of spherical drops, surrounded by their own vapour (fig. 4).

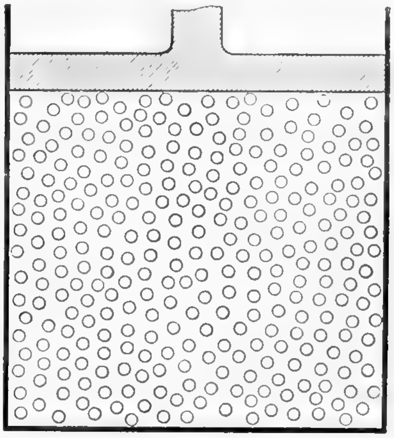

FIG. 4.

The state of affairs is now reversed, for instead of having vapour in contact with a concave liquid surface, and therefore at a pressure less than ϖ_0, the normal saturated vapour pressure, we have saturated vapour in contact with convex liquid surfaces, and therefore at a pressure ϖ, greater than ϖ_0.

Hence, in this limit, we may take the pressure on the enclosing piston to be that of the saturated vapour, namely ϖ, the mass will be subject to an external pressure greater than ϖ_0, namely $p = \varpi$, and this brings us into the region CN (fig. 2) of the isothermal which lies above the normal pressure line BD. In this it is assumed that the mass is largely in the condition of saturated vapour, and that the liquid exists as a system of equal spherical droplets, swimming in their own vapour.

If the drops were of different radii, equilibrium would be impossible, as evaporation would take place at the surfaces of the smaller drops, and condensation at the surfaces of the larger. This instability is made evident by the equation

$$\varpi = \varpi_0 + \frac{2T}{r} \cdot \frac{\rho_2}{\rho_2 - \rho_1},$$

which shows how the vapour pressure increases as the radii of the liquid drops diminish, and when the drops are small, ϖ may exceed ϖ_0 by a considerable quantity.

There is a limit, however, beyond which, if the radii of the drops be diminished, the foregoing equation will cease to apply, and the pressure ϖ, after reaching a maximum, will gradually diminish and finally recede to the value ϖ_0, when the drops of liquid vanish. This is the process which takes place along the falling part ND (fig. 2) of the isothermal. Similarly, in the initial phases of the transformation here imagined, namely, when small bubbles are beginning to be formed within the mass, it is clear that equation (2) ceases to apply, when the bubbles are so small that they cease to possess the distinctive properties of vapour, and it consequently follows, that although ϖ may be very much less than ϖ_0, at some part of the branch BMC, yet a condition is attained with bubbles of a certain diameter, in which ϖ is a minimum, and from which it increases in both directions, to the normal vapour pressure ϖ_0.

Thus, the part BM (fig. 2) of the isothermal is accounted for, and therefore the whole succession of conditions represented by an isothermal, such as that imagined by James Thomson, is rendered conceivable. Such a succession, of course, cannot be regarded as realisable, for although the condition represented by every point of the curve is shown to be possible, and one of equilibrium, when the bubbles (or drops) are all of the same size, yet the equilibrium is essentially unstable, for when there is any departure from uniformity, all differences tend to become exaggerated, and the mass may depart from the condition of equilibrium with explosive violence.

It is interesting to note, that the mass may be transformed from the condition B to the condition D by two distinct routes of transformation—one along the right line B D, in which the condition is stable, and the other along the curved path BMCND, in which the condition is unstable,—yet the principle of the conservation of energy forces us to conclude that the work done against external pressure, while the mass expands from B to D, must be the same in the two cases, and for this reason it has been concluded, that whatever the shape of the curve AMND may be, the area of the loop BMC must be equal to the area of the loop CND. At first sight we might apply the same reasoning to the transformation from B to C, or from D to C, and rush to the conclusion that the area of each loop must be zero, or else that we are here presented with a violation of the principle of conservation of energy.

But it must be remarked, that although at the point C of the diagram, the mass, in both cases, has the same temperature, pressure, and volume, yet in one case all the vapour is collected into one portion of the chamber, and all the liquid into the other, whereas in the other case, the vapour and liquid are not distinctly separated from each other, but intermixed in some way so as to occupy the whole space as an apparently homogeneous mass. Hence the point C represents two distinct conditions of the mass in which the pressure, volume, and temperature are the same, but in which the internal energies may differ very considerably. Thus, although less external work is done in passing from B to C along the curve BMC, than in passing along the right line BC, yet in virtue of the arrangement of the mass, the internal energy at C, in the former case, may be considerably greater than in the latter.

This, indeed, must be the case if the arrangement of the mass be of the bubble and drop nature here suggested. For, if a given mass, existing partly as liquid and partly as vapour, in such a way that the liquid is collected together in one part of the containing vessel, while the vapour is all collected in the remainder (as ordinarily occurs in practice), and if we desire to change it from this arrangement into one like that described above, in which the vapour is disseminated through the liquid in bubbles, or in which the whole vessel is filled with vapour and drops, a certain amount of work must be done in order to effect the transformation—namely, the equivalent of the surface energy possessed by the enormously increased surface area of the bubbles and drops in the new condition. Thus, although less external work is done in passing along the isothermal BMC than along the rectilinear path BC, yet the mass in the former case possesses more surface energy than in the latter, and the excess of external work in the latter transformation is represented in the former by an excess of internal work spent in generating the excess of surface film.

Similar remarks apply to the portion CND, for in passing along this curve, the external work done is greater than that performed in passing along CD, but this is compensated by the destruction of the surface film. Thus, along BMC, there is on the whole a creation of surface film with less external work, and along CND there is destruction of surface film accompanied by increased external work—the excess in the former being equal to the defect in the latter.

In conclusion, it may be remarked, that the views here put forward seem to have an important bearing on many interesting questions connected with the boiling points of liquids, and the manner in which they are affected by the presence of dissolved salts. It is sufficient to merely point out, at present, that obviously any operation which increases the surface tension of the film separating a liquid from its own vapour, will also raise the boiling point, for when T is increased, a greater vapour pressure ϖ within a bubble will be required in order to enable it to expand against a given external pressure. This prediction of the theory appears to be in accordance with the observed facts.

TRANSACTIONS (SERIES II.).

VOL. I.—Parts 1–25.—November, 1877, to September, 1883.
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VOL. III.—Parts 1–14.—September, 1883, to November, 1887.
VOL. IV.—Parts 1–14.—April, 1888, to November, 1892.
VOL. V.—Parts 1–13.—May, 1893, to January, 1896.

VOLUME VI.

PART

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THE
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VOLUME VI.—(SERIES II.)

V.

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(Plates V. and VI.)

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(Read June 26, 1895.)

In 1861 Clerk Maxwell read a Paper before the Royal Institution of Great Britain, "On the Theory of Three Primary Colours."*

In this Paper he announced very briefly his discovery of a method whereby the colours of nature could be photographically reproduced by the superposition by optical projection of three coloured images. How far the method then described by Maxwell embodies the theory and practice of recent efforts in this direction must be judged from his own words.

After displaying upon the screen the three primary colours by passing a beam of white light through three suitably coloured solutions he proceeds to show the synthesis of the spectrum by projection: "The graduated intensity of the primary colours in different parts of the spectrum was exhibited by three coloured images, which when superposed on the screen gave an artificial representation of the spectrum." Then follows:—

"Three photographs of a coloured ribbon taken through the three coloured solutions respectively were introduced into the camera, giving images representing the red, the green, and the blue parts separately as they would be seen by each of Young's three sets of nerves separately. When these were superposed a coloured image was seen which, if the red and green images had been as fully photographed as the blue, would have been a truly coloured image of the ribbon. By finding photographic materials more sensitive to the less refrangible rays, the representation of the colours of objects might be greatly improved."

In this description not only is the method of colour synthesis by triple projection described, but in the words defining the mode in which the three photographic images are to be secured, "as they would be seen by each of Young's three sets of nerves separately," the complete theory of composite colour

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* Collected Papers, vol. i., p. 449.

photography is specified. While this definition of the theory is clear, the wording of the report of his lecture leaves some doubt as to the actual nature of the light filters used by Maxwell. There is evident confusion in the wording of the report, as appears in the reference to the "three photographs introduced into the camera."

I cannot but think, however, that the three solutions referred to are those used by Maxwell to transmit the three primary colour sensations. This view is strengthened by his previous statement that the red sensation is stimulated most by the red wave-lengths, but also by the orange and yellow wave-lengths, &c. This mistake would quite explain his use of the solutions transmitting the primary colours.

It is further of interest to note that at a yet earlier date Maxwell describes his idea of using our knowledge of the colour sensations for obtaining photographs in natural colours. As early as 1855, in a paper read before the Royal Society of Edinburgh, "On Experiments on Colour as perceived by the Eye,"* he describes how by triple projection of three photographs, one taken through a red glass, a second through a green glass, a third through a blue glass, the final positives being backed respectively by red, green, and blue, an image in natural colours could be obtained. In this case also he expresses the view that the several colour sensations are most stimulated by the wave-length, which most nearly represents the sensations, a statement which is, as we will presently see, erroneous.

I think, therefore, that Maxwell, while correctly defining the theoretical conditions governing the choice of light filters for obtaining the negatives, yet having himself an erroneous notion as to the rays which cause the maximum stimulation of the primary colour sensations, fell into a logical error in practising his own invention.

For many years after Maxwell's time triple, quadruple, or even more manifold projection were suggested by various writers; notably by Collen, Ducos du Hauron, and von Ransonnet. Maxwell's correct theoretical ideas seem to have been entirely unknown to these writers, and were not indeed revived till 1886, when Mr. Ives of Philadelphia proposed just such a method, and applying modern resources showed how fully justified was Maxwell's prediction that, with improved plates, the representation of colours could be greatly improved. To Mr. Ives is also due the credit of clearly defining how the "taking" screen should be chosen. It must be observed that to Professor H. W. Vogel's great discovery in 1873, of the action of certain analine dyes in remedying the colour blindness of the salts of silver, the possibility of advance in this direction is entirely due.

As what follows involves an application of Maxwell's principles in a new

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* Trans. Roy. Soc. Edinb., vol. xxi., pt. II.

manner, it is requisite here to describe, briefly, Maxwell's method of composite colour photography as developed by Mr. Ives.

Composite colour photography deals with the subjective reproduction of all visible wave-lengths in two stages; a photographic analysis and an optical synthesis. In the first operation the several wave-lengths are caused to produce three separate photographic images according to their physiological activity in exciting the supposed fundamental red, green, and violet sensations. Suppose, as a simple example, that we are photographing the yellow of the spectrum near the D line. One of the plates must record an image of the spectrum at this point having a density of silver deposit corresponding to the degree in which this wave-length can excite the red-seeing nerve, and a second must acquire a density corresponding to the degree in which this same wave-length can excite the green-seeing nerve. The third plate records no impression, for the wave-lengths near D excite no violet sensation; but this yellow sensation is the resultant of two physiological effects only, a red and a green sensation in certain proportions. The nature of these proportions can be ascertained by colour measurements effected upon colour sight. We have now obtained three negatives possessing densities of silver deposit corresponding to the degrees in which the three several fundamental colour sensations are excited. These degrees of density will be interpreted as degrees of transparency in the positives. The first positive, if backed with a red glass, will transmit a quantity of red light corresponding to the intensity of the physiological excitation of redness in the 'red' nerves; the second, backed with green, similarly represents the stimulation of the 'green' nerves by the yellow colour of the object; the third positive is backed with blue-violet glass, but is quite opaque, and no violet light is transmitted through it. The projection now of all three images superposed upon the screen forms the second stage of the procedure; the optical synthesis of the original colours. The eye, regarding the superposed image, receives in fact the same amounts of red and green sensation, and experiences the same absence of violet sensation which would have attended the formation of the image of this part of the spectrum upon the retina.

This process, if accurate reproduction of colour is sought, necessitates the use of two distinct sets of colour selective screens; for the analysing screens will by no means possess the tints ultimately required in the optical synthesis. This will be evident when it is considered that the wave-lengths which most strongly stimulate the several fundamental sensations are not those which most nearly represent those sensations to the normal eye. The C red, for example, is not the wave-length which most strongly stimulates the red sensation; a wave-length which appears orange to the eye possessed of both red and green vision, will far more effectively excite the red sensation. Hence, in order to photograph the wave-lengths of the spectrum, according as they excite the red sensation, we require to produce a greater photographic effect by the D wave-lengths than by the C wave-lengths. To effect this analysis of the light, a screen transmitting as a predominant wave-length, a wave-length near D, must be used for obtaining the image which is to represent the appreciation of light peculiar to the 'red' nerves. Such a screen has a yellow-orange colour, which is not the sensation excited in or transmitted by the 'red' nerves. In the optical synthesis this must afterwards be represented by a C red colour. The same remarks apply to the other screens.

In the foregoing description I have spoken of the method as if based directly on actual colour sensation curves. Upon the revival of Maxwell's method, writers quoting from Maxwell fell into this mistake. Although supplying a convenient terminology in conveying a general idea as to the nature of the procedure, it is necessary now to be more precise.

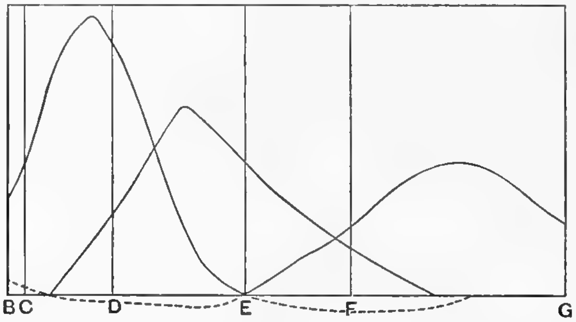

FIG. 1.

Maxwell's curves (fig. 1) are not true colour sensation curves,* but represent the subjective synthesis of the prismatic spectrum out of three chosen wave-lengths—a red, a green, and a blue-violet. The question as to how far one or all these chosen wave-lengths may excite more than the one set of nerves remains over, and indeed can only be gone into by examination of abnormal colour vision. In Kœnig's curves of colour vision, colour sensations are plotted to the normal spectrum. These are shown in the named curves of fig. 2.

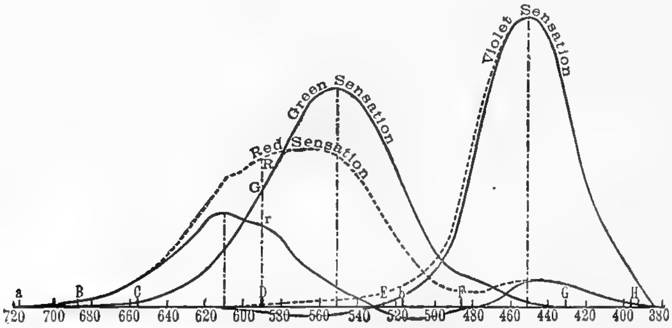

FIG. 2.

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* Abney: "Colour Vision," Tyndall Lectures, 1895.

If, from the knowledge afforded by Kœnig's curves of the compound nature of the green sensation, Maxwell's curves be examined with reference to their suitability to serve the purposes of the photographic method, it will be found that, assuming Maxwell's E green to excite the proportionate amounts of red and violet sensation revealed by Kœnig's curves, a correct synthesis of the F green by Maxwell's curves is impossible. Although such a comparison is not strictly allowable owing to the red and violet curves of Maxwell being based on different wave-lengths to those used by Kœnig, the fact of some inaccuracy is certain. This fact will appear if the spectrum is photographed according to Maxwell's curves. The blue-green will then be found to be reproduced too yellow in tone.

In order to apply the colour sensation curves of Kœnig to the photographic method, we have to find by trial examinations of his curves the green most suitable for backing the 'green' positive; for we see that the several green wave-lengths excite very different amounts of red and violet sensation. We find as suitable a wave-length a little to the left side of the E line, about 550 $\mu\mu$. If we take this colour to back the green positive, we must, in order to find the correct red and violet curves which are to control the densities of the red and violet images, replot the red and violet curves with allowance for the proportionate amounts of red and violet which will be carried to all those points where in the image of the spectrum the green curve operates. The red and violet curves must be lowered by amounts obtained by ascertaining from the height of the green curve at any point the amount of red and violet sensations excited by the amount of our selected green present at that point.

The necessity for the alteration of the curves will, perhaps, be more clearly understood if it be considered what consequences would ensue if we take three negatives of the normal spectrum through light filters, selecting according to the unaltered Kœnig's Colour Vision curves.

In the process of synthesis we would, in this case, have upon the screen, at the point D (suppose) of the projected image a quantity of fundamental red represented by the height DR, and of green represented by the height DG. Now, whatever wave-length we make choice of to excite the fundamental green sensation in the optical synthesis, we inevitably excite both the red and violet sensations by the chosen wave-length. If we adopt the E green, we see by the curve that this wave-length excites the large amount of red sensation shown by the vertical height of the red sensation curve at the point E, and the small amount of violet sensation measured to the violet sensation curve at this point. In projecting then at the point D of the image a quantity of the E green, according to the height DG, we excite amounts of red and violet sensation which can be ascertained by comparing the height DG with the height of the green sensation curve at E. At D we are, in fact, not only projecting the amount of red sensation DR, but adding the large quantity of red sensation involved in the quantity DG of E green, as well as adding some violet. The image of the spectrum will, accordingly, be much too orange at this point. It is evident that the error arises from the compound nature of the sensations attending the excitation of the green sensation, over which we have no control. Hence it is that deductions from the red and violet curves are necessitated whenever green light is required in the synthesis; that is, wherever the green-sensation curve overlies the red or the violet sensation curves. Maxwell constructed curves to which the red and violet constituents are diminished by the amount of red and violet sensations conveyed in the green chosen by him as the fundamental green, and by him assumed to excite only the green sensation.

As the results of trials on Kœnig's curves made with the object of ascertaining the green wave-length involving least negative red and violet, the accompanying figure 2 shows in the full lines derived curves which, in their general location, resemble Maxwell's, but are based on a more correct choice of the fundamental colours, and connect our photographic process directly with the colour sensation curves. It is seen that the violet curve is but little altered, and the red considerably altered. The amount of negative colour (which cannot be realised) is inconsiderable. The outcrop of the red-sensitive curve in the violet is not difficult to realise in the use of orange dyes for the red-taking light filter, which in most cases show some transmission of the violet wave-lengths.

Although it is possible that the compound nature of our green sensations may deny absolute accuracy to this method of colour photography, still my own results on the curves just described, and the results of Ives and others on modified Maxwell curves, appear to show that a degree of accuracy baffling the criticism of the ordinary untrained eye may be attained, and that in the reproduction of the most complex tints.

The symmetry of the derived curves renders their application easy. The transmission of light through a pigment is not limited generally to a small group of predominant wave-lengths, but falls off uniformly at either side in the directions of longer and shorter waves. If we choose the pigments used on the analysing screens so that their predominant transmissions are at three points in the spectrum indicated by the axis of symmetry in the three curves, these being nearly symmetrical, very accurate results are obtained. The positions of these axes of symmetry are shown by the vertical dotted lines. Accordingly, I make the colour of the red-taking screen that of the spectrum at a point displaced to the red side of D by about one-sixth the interval D to C; for the green and violet-taking screens the correct tints are found in the same manner by scaling from the figure. Good results are thus obtained, but I do not assert that these details of procedure are final.

Although referred to in what has preceded, the necessity of the separate screens, according to Maxwell's theory, cannot be too clearly understood. The necessity will be evident if the effects of photographing, and viewing the spectrum through the same screens be considered. Evidently, if these are the fundamental colours, the final result will show colour at three separated regions of the spectrum only. The red, green, and violet wave-lengths would alone affect the plate, and the purer we choose the fundamental colours the more restricted would the action be, and the less the action of the intermediate wave-length. On the other hand, if the negatives are taken through the 'taking' colours, and the positives subsequently viewed through the same, we can, of course, have no pure red or violet upon the screen, for, in fact, these colours are entirely absent from our individual images. In short, the three primary colours by which correct syntheses of all colours of the spectrum can be alone made are indispensable to the final projection, but are quite unsuited to serve as the taking colours, as they will transmit to the plate only a limited selection of the various wave-lengths of nature, and that not at all according to the degree which these excite "Young's three sets of nerves separately." The use of the same screens for taking and viewing having intermediate tints can, of course, only mitigate the evils referred to.

It is further necessary to observe that, as no photographic plate has as yet been prepared which is uniformly colour sensitive, allowance must be made for this in the choice of pigments to act as light filters, and only by careful photo-spectroscopic work can these be selected.

Had we a plate possessing a uniform distribution of colour sensitiveness the curves could be directly applied to the choice of colours, and these be selected simply by eye observation of their effects upon the solar spectrum.

Any method of photography in natural colours must possess the characteristics not only of accuracy of colour rendering, but also of convenience of application and permanency of colour, if it is to possess value as a scientific method. For use under the various circumstances of travel the naturalist requires a method no more cumbersome than the present dry plate. In the method of composite colour photography, as described, the ordinary camera will not serve. The cumbersome necessity of obtaining three images remains, and subsequently no concrete image in natural colours is actually obtained. One can only be realised by triple projection upon a screen, or by using some optical contrivance which, by the aid of reflectors, enables all three images to be simultaneously projected upon the retina.

I now proceed to describe a mode of applying the foregoing principles which is free of the objection of cumbersomeness, and which enables us to realise a concrete image in transparent colours. A plate is finally produced which may be held in the hand, regarded against the light, and which bears an image of the object in natural colours, or such as are so nearly accurate as to seem so to the eye. In this new method there is but the one image photographed. The ordinary camera, lens, and backs, &c., are used without modification. The first-class isochromatic plates in the market, which are sensitised down to the C red, will give very good results.

In the new method the idea is to carry the application of physiological principles still further, and divide up the plate like a hypothetical subdivision of the retina, so that all over the plate there should be minute regions uniformly distributed wherein the sensitive silver salt is excited to become reduced to the 'photogenic' material in the same degree in which the sensations of redness, greenness, violetness, would have been actually excited in the several nerves of the retina had the image been formed upon it. Development builds upon this photogenic material the denser silver deposit, and ultimately in the positive the amounts of the sensations are registered in the degrees of transparency of the successive regions. The lined screen which can bring about this will only show its individual colours when placed under the microscope. It is then seen to consist of closely ·ruled adjacent lines in reddish-orange, yellowish-green, and blue tints. This screen, applied closely to the sensitive surface, analyses the image in the camera. The screens I have used hitherto are coarse, about 200 lines to the inch, and even with this coarseness will show plainly, I regret to say, the imperfections of the only apparatus at my command in preparing these screens. I may observe, in passing, that the colours are ruled on in pigments made up as inks in gelatine and gum arabic or dextrine, and upon plates coated with a preliminary layer of gelatine. Such lines may be put on so close as 800 or 1000 to the inch. With between 300 and 400 to the inch, however, the eye is no longer annoyed by the structure of the plates. The lines may also be ruled on celluloid or on translucent paper.

The appearance of both negative and positive taken through such a screen is shown in Pl. VI.

Recalling now that the lines upon the positive register in their degrees of transparency, the degrees in which the three-colour sensations would have been excited, it becomes apparent that to complete the physiological parallel we must convert these degrees of transparency to quantities of the red, blue, and violet colour sensations. This is done by a second screen, which carries red, green, and violet lines to the same gauge as the taking screen. We apply this to the positive, and as we move it over the image, waves of every tint of colour appear till that position is reached where the red lines fall over the lined areas recording red sensation, and so for the others. The picture now suddenly appears in vivid colour and with all the realism and relief conferred by colour and colour perspective.

Plate V. shows a photo-lithographic reproduction of four of such photographs in colours, the full size of the originals. The originals being transparencies show a greater richness of colour. The reproduction too does not aim at reproducing the minute structure in simple colours of the plates. This could only be observed by considerable magnification of the original. This was inevitable, but is to be regretted as the remarkable, indeed startling, experiment is denied to the observer of assuring himself by aid of a lens that the whites are composed entirely of vivid lines of red, green, and violet; the yellows of red and green; and that the combinations of the three primary colours, together with the black of the silver deposit, afford all the tints, however subtle, or however complex; tints many of which are extra-spectral, as the pinks, purples, and browns.

It is further to be remarked that the reproduction of the grained appearance of the plates by the artifice of printing a grating of black lines upon the pictures is not, of course, fair to the originals. For in the reproduction these overlie the less saturated colours and complex tints equally with the saturated colours, whereas it is involved in the photographic process that where complex colours act, or colours which are not saturated, the action being more uniform over the three sets of lines, will result in a more uniformly transparent surface. Thus, in the white upon the shawl of the photograph of an Irish peasant girl, there should be only the faintest grain, and also upon the high lights of the face, and upon the faces of the soldiers in the picture beneath, &c. In spite of these drawbacks the reproduction fully serves the purpose of showing the stage this branch of photography had reached at the time this communication was brought before the Royal Society, and my best thanks are due to the Royal Dublin Society for reproducing these pictures.

The following particulars regarding these four pictures may be of interest:—

The photographic plates upon which the negatives were taken were Lumière's panchromatic series, sensitive, as photographs of the spectrum show, down to the C red. Development was with metol and hydroquinone mixed.

The "Irish Peasant Girl" is from a water-colour picture by Miss Steel of Dublin; reduced in photographing about one-third. The exposure was fifteen minutes, indoors, near a window; stop F/22; a long-focus ($11\frac{1}{2}$ inches) lens being used. A pale-coloured picric acid stained gelatine screen served in all cases to cut off the ultra violet and modify the action of the visible violet.

On the truth of this reproduction I have only to observe that when original and photograph have been exhibited together even trained observers could point to no error. It is to be remarked, however, that in all cases this degree of truth is not attained upon first trial. The correct exposure has to be found, but, once found, work upon objects of like nature subjected to like conditions of light, &c., is easy and rapid, and the results certain.

The adjoining picture was direct from nature. The reproduction lacks the full richness of the browns, and above all the velvety texture of the petals which was very striking in the original especially upon the lower blossoms. It will be noticed that the grain is less conspicuous upon this than upon the other pictures. This is because the photograph was taken through a screen ruled in two tints only, the red-taking and the green-taking. In short, it represents the bunch of wall-flowers as they would be seen by violet blind sight. The reds, browns, and yellow appear unaffected; the greens, however, are, as will be noticed, somewhat harsh.

The group of bandsmen was taken during Trinity College athletic sports, June, 1895. Exposure four seconds, F/10, sunny, 4 o'clock in the afternoon. The lens was a Goertz anastigmatic.

The green glass bowl represents an Uranium glass possessing fine dichroic effects in yellow and green. These effects hardly reappear in the reproduction, but the effect of transparency is correct. This picture was one of the earliest taken.

Other subjects have also been dealt with. The solar spectrum taken according to Maxwell's curves is seen to extend on the photograph from the C red to the H lines. The blue-green is not quite correct. Many of the Fraunhofer lines are reproduced. The reproduction of bright metallic objects has been tested by photographing a highly lacquered microscope in brass and German silver. Various interiors, as the hall of the Engineering School, Trinity College, have been taken. Among out-of-door subjects, a view in the quadrangles of Trinity College shows the new red-brick buildings; the red hawthorns in blossom, and figures in the foreground in grey and black suits, with University Rowing-Club blue on straw hats. Other views of the College Park; fields and chalets in Switzerland (F/18, 3 secs. September, 10 o'clock, clear sunshine). A portrait from life, of Mr. Henry H. Dixon, of Trinity College, shows that the most faithful reproduction of flesh tints is possible. A bunch of pansies in a Japanese bowl, reproducing the velvet of nature upon the darker hues of blue-black and tawny-brown, suggests how the association of the experiences of other senses underlies our visual inferences. The fact that Maxwell's photographic method, based on the three-colour theory of vision, can thus interpret nature, appears strong confirmation of Young's theory.

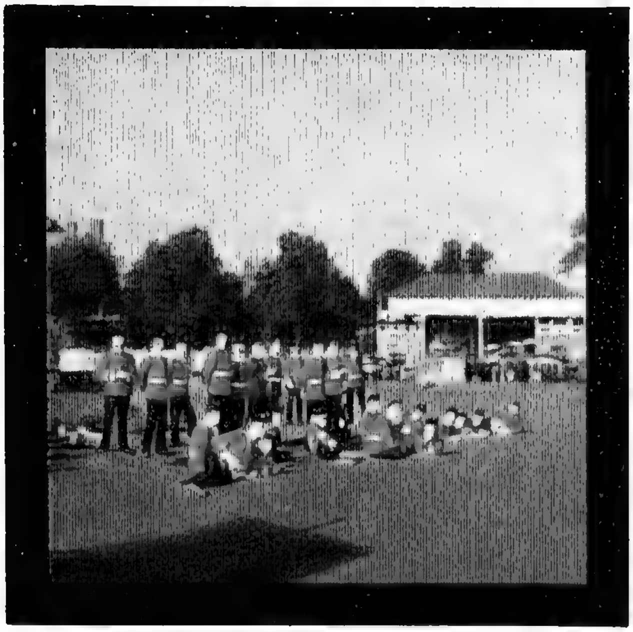
It is to be remembered that these results are attained by no new photographic operations. It is necessary to use good orthochromatic plates sensitised into the red, and also to have affixed in the lens an orthochromatic screen cutting off the ultra-violet light in the usual manner. The exposure is longer than the ordinary exposure, for we can of course only use visible light, and of this a part is stopped by the taking screen. The ordinary backs may be used. The displacement of the sensitive film from accurate register with the ground-glass camera screen, owing to the presence of the taking screen in front of it, may be corrected (if thought necessary) by simply reversing the surface of the ground-glass camera screen, turning the muffled side outward. This secures that the image will be accurately focussed in the plane of the sensitive surface. Negatives and positives may be used as ordinary negatives or positives till it is desired to recall the original colours. Thus, for those who wander with the camera, the possession of but the one seeing screen to test results is sufficient, and of course the one taking screen suffices to take an indefinite number of plates.

These considerations lead us naturally to observe that the registration of colour being really carried in the silver image, which with very little care in manipulation may be made permanent, secures that the colours are permanent. A faded screen may at any time be made good by a fresh screen; the colours in all cases being spectroscopically chosen, we are assured of the reproduction of the original colour. In this aspect the necessity of the detached colour screen is no disadvantage, but rather a necessary safeguard against the inevitable fading attending most pigment colours.

The question of course naturally suggests itself if results on paper, that is results seen by reflected light, are not also possible on the principles described. My early experiments in this direction were not encouraging. The difficulties of correctly superposing the viewing colours upon a paper positive are considerable. For book illustration, the correct and sufficiently rapid register of printing surfaces, having the required minuteness, presents grave difficulties, and in all such printing processes the truth of colour vanishes with the uncertainty attending the amount of colour transferred to the paper. Again, if any fixed combination of the colours and the sensitive salt is sought for, the difficulties of preserving these colours during development or toning, &c., present themselves. Finally, perhaps the gravest difficulty resides in the enfeeblement of the reflected light, already enfeebled by the inevitable loss due to absorption in the reflecting material.

NOTE ADDED IN THE PRESS.

I have recently ascertained that Ducos du Hauron 30 years ago, at the conclusion of a lengthy French patent for colour reproduction by triple projection, suggested the use of a screen lined in colours for combining the three images in one. The fact that his theoretical colour principles were erroneous and that consequently no practical result is possible on the procedure he suggests, probably accounts for the absence of any record of anything actually accomplished in this direction.—(*June* 3, 1896.)



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[October, 1896.]

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VI.

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(Plates VII. to X.)

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[Read JANUARY 23, 1895.]

THIS communication is based upon a small collection of Actiniaria which was entrusted to one of us for description by Professor W. Baldwin Spencer of the Melbourne University. The specimens were, as a rule, well preserved in alcohol; and they were accompanied with some cleverly executed coloured drawings, which we regret we are unable to reproduce in colours. Various circumstances delayed the completion of the undertaking; and as several other forms were forwarded to us for examination by Prof. F. Jeffrey Bell, of the Natural History Department of the British Museum, and by Prof. W. A. Herdman, of University College, Liverpool, we decided to publish the descriptions of these various specimens in one paper.

The number of genera and species is too small and unrepresentative to warrant a disquisition on the classification of the Actiniaria in general.

With the exception of one or two recent papers, full references to which are given in the text, the authors referred to are so well known that we have not occupied space by giving the particulars of publication. These are given at length in Dr. Andres' Monograph, and in the "Revision of the British Actiniæ": I. Trans. Roy. Dub. Soc., 1889; II. Trans. Roy. Dub. Soc., 1891.

The following is a list of the eleven species which we now describe:—

ZOANTHEÆ.

Brachycneminæ.

Zoanthus Shackletoni, n. sp.; Adam's Bridge.
Gemmaria Canariensis, n. sp.; Canary Islands.
Palythoa Gregorii, n. sp.; East Africa.
,, **liscia**, n. sp.; East Africa.

Macrocneminæ.

Epizoanthus egeriæ, n. sp.; South China Sea.

PROTACTINIÆ (PROTANTHEÆ.)
  Corallimorphidæ.
    Corynactis Australis, n. sp.; Port Philip.
  Aliciidæ.
    Cystiactis tuberculosa, (Quoy et Gaim.); New South Wales.
HEXACTINIÆ.
  Actiniidæ (Antheadæ).
    Actinioides Spenceri, n. sp.; Port Philip.
SAGARTIDÆ.
  Sagartininæ.
    Sagartia Carlgreni, n. sp.; Port Philip.
  (? sub-family).
    Mitactis, n. g.
    Mitactis Australiæ, n. sp.; Port Philip.
    ,, **similis**, n. sp.; Port Philip.

ZOANTHEÆ.*

BRACHYCNEMINÆ, (Haddon and Shackleton), 1891.

ZOANTHUS, Lamarck, 1801.

Zoanthus Shackletoni, n. sp.

(Pl. VII., fig. 1.)

Form.—Body smooth, walls thin, and in some so transparent that the gonads and mesenteries can be distinguished; club-shaped when contracted, narrowing proximally either gradually or suddenly. Polyps in clusters, buds springing from the narrow bases of the polyps and rarely from the stolon. Stolon feebly developed, occasionally forming very small flattened expansions.

In contracted spirit specimens, the following regions can be distinguished:—an uppermost region, a gonadial zone, an inferior mesenterial region, and a pedicel passing into the stolon.

Colour.—In spirit specimens the column exhibits various shades of buff according to the body region.

Dimensions. — Average length of contracted specimens, 13 mm.; average diameter, 4 mm.

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* For a definition of the Zoantheæ, and of its two sub-divisions, and the various genera, the reader is referred to the Trans. Roy. Dub. Soc., IV. (Ser. II.), 1891, pp. 626–633.

Locality.—Pamban, Ramesvaram Island. Adam's Bridge (between India and Ceylon), several colonies growing on nullipores, and associated with numerous small delicate sandy worm-tubes, which, along with other calcareous particles, adhere strongly to the stolons.

We have associated with this species the name of our friend and colleague Miss Alice M. Shackleton.

Body-wall (Pl. VIII., fig. 1).—Very thin throughout, thickening a little in the region of the proximal sphincter muscle. The wall of the column is bounded externally by a distinct brownish cuticle, with a thick deposit of brownish granular material with foreign particles, including frustules of diatoms. Beneath this cuticle, and between it and the ectoderm, is a thin layer of mesoglœal substance, "sub-cuticula,"* connected by strands of mesoglœa through the ectoderm to the mesoglœa proper. Below the upper portion of the column the cuticle and sub-cuticula present a somewhat dendriform appearance, best seen in longitudinal sections. In some cases the brownish cuticular substance is almost entirely enclosed. This dendriform appearance may be due to the unequal contraction of the cuticle and "sub-cuticula." In the ectoderm, the cells have become so vacuolated that only nuclei and strands of protoplasm remain.

The mesoglœa is thin, and contains cell-islets. A canal system extends transversely and longitudinally; and in the lower part of the column these canals are found to communicate with the basal canals in the mesoglœa of the mesenteries. The contents of the canals stain very deeply, and zooxanthellæ occur, especially in the lower part of the column and in the stolon. The endoderm is well developed, and crowded with zooxanthellæ. The endodermal muscle is only slightly developed.

Capitulum.—In the capitulum, the ectoderm becomes continuous, non-vacuolated, and without the cuticle and sub-cuticula. The mesoglœa is very thin, and the endoderm crowded with zooxanthellæ.

Sphincter muscle (Pl. VIII., fig. 2).—The sphincter muscle is double and mesoglœal. The proximal, or lower, portion is well developed. The cavities in the mesoglœa are hollow, with only a very thin lining of muscular fibres; they are transversely elongated above, but rounded and more numerous below. The distal, or upper portion of the muscle is much smaller. In contracted specimens, there is a deep fold of the body-wall between the two parts of the sphincter.

Tentacles, Disc, and Œsophagus.—The ectoderm is without the cuticle and the "sub-cuticula," and is non-vacuolated. The mesoglœa is thin; the endoderm is thick, crowded with zooxanthellæ, and almost fills up the lumen of the tentacles.

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* *Cf.* the remarks on this structure by Prof. A. R. von Heider, "*Zoanthus chierchiæ*, n.sp.": Arbeit. Zool. Inst. Graz., v. 1895, p. 118.

Mesenteries.—The arrangement of the mesenteries is brachycnemic. They are straight, and, owing to their number and well developed endoderm, almost fill up the cœlenteron. The mesoglœa is very thin, except parietally where it surrounds the large basal canal. These are mostly circular in transverse section (Pl. VIII., fig. 3) except in the upper part, where they become ellipsoidal. The canal is filled with a deeply staining tissue. These basal canals are in communication with the mesoglœal canals in the lower part of the column. In longitudinal sections they can be traced from near the base along the greater part of the length of the column.

The musculature is weak, the mesoglœa being only slightly plaited.

Gonads.—Female gonads are developed in many of the specimens. They occur in the mesenteries at the upper third of the contracted column.

Zoanthus Shackletoni has an external resemblance to *Z. sociatus* (Ellis), which has been minutely described and figured by McMurrich (1889). This latter species is very common from the West Indies. We have communicated with our friend Prof. McMurrich, and sent him specimens of our species. He informs us that its size is only about one-third of that of *Z. sociatus*; that the sphincter muscle is entirely different in the two forms, since, in *Z. sociatus*, the proximal sphincter is relatively very much longer than in our species, and the outlines of the compartments of the lower part of these muscles is also very different. The basal canals are elongated in section in *Z. sociatus*, as shown in McMurrich's figure, but rounded in ours. As before mentioned, the remarkable appearance of the peripheral part of the body-wall may be due to unequal contraction, but this need not prevent it from forming an additional diagnostic feature, and so far as we are aware it is unique.

Our species can also be readily distinguished from other described species of Zoanthus (*cf.* Trans. R. D. S., iv., 1891, p. 629). Amongst other characters, it differs from the more recently described *Zoanthus chierchiæ*, Heider, in its form, and in the character of its sphincter muscle, ectoderm, and cuticle.

GEMMARIA, Duchassaing & Michelotti, 1860.

Brachycnemic Zoantheæ, with a single mesoglœal sphincter muscle. Solitary, or connected by cœnosarc. The body-wall is incrusted. The ectoderm is usually discontinuous, but may be continuous. Lacunæ and cell-islets are found in the mesoglœa. Diœcious.

This definition of the genus differs only from that given in the Report of the Zoantheæ from Torres Straits (1891), in the fact that the polyps may be connected by cœnosarc. McMurrich (1889) considered that, in *Gemmaria isolata*, the polyps may be connected, but the present species is the first in which the presence of the cœnosarc is undoubted.

The history of the genus will be found on page 687 of the above Report. Hitherto, only the following four species have been recognised as belonging to the genus :—*G. rusei*, Duch. & Mich., from St. Thomas (1889); *G. isolata*, M^cMurr., from the Bahamas (1889*a*) ; *G. Macmurrichi*, Hadd. & Shackl., and *G. mutuki*, Hadd. & Shackl., from Torres Straits. We now add a description of a new species, *G. Canariensis*, from the Canary Islands.

Gemmaria Canariensis, n. sp.

(Pl. vii., fig. 2.)

Form.—The column is erect, rigid, and of about equal diameter throughout, except at the upper part of contracted specimens, which is swollen, and possesses about 24 radiating ridges. The ectoderm has almost entirely disappeared. Where present, it is coarse in appearance. The polyps rise from a thick, firm, continuous cœnosarc.

Colour.—The true colour is removed by the alcohol in which the colonies are preserved. They are now of a dark purple tint, due to the pigment from an Aplysia placed in the same jar. This is largely removed on placing the specimens in acid.

Dimensions.—Height, 13 mm. ; average diameter of column, 3 mm. ; greatest diameter capitular region, 5 mm.

Locality.—Canary Islands. Two colonies, each with three or four connected polyps.

The specimens were kindly placed at our disposal by Prof. W. A. Herdman, of University College, Liverpool.

Body-wall (Pl. viii., fig. 4).—In the two specimens cut for longitudinal and transverse sections, the ectoderm of the column is almost absent. Where, however, traces do occur, it is continuous, of considerable diameter, and contains numerous zooxanthellæ. A thin cuticle is present, containing frustules of diatoms.

The incrustations consist mostly of siliceous and calcareous sand-grains and sponge spicules, but they are all limited to the outermost part of the mesoglœa and to the ectoderm. The incrustations give the surface of the column a roughened appearance where the ectoderm is wanting.

The mesoglœa is moderately thick in the upper part of the column, and increases considerably towards the base. It is crowded with cell-islets of variable size. The larger of these are mainly limited to the central zone of the mesoglœa.

The larger cell-islets contain zooxanthellæ. There is not much tendency to the formation of lacunæ. Single cells with elongated fibrils stretch across the mesoglœa.

The endodermal muscular layer is well developed, but less so in the lower part of the column. The endoderm is uniformly developed, of medium height, and crowded with zooxanthellæ.

Sphincter muscle (Pl. viii., fig. 5).—The sphincter muscle is single, mesoglœal, and elongated. The hollow cavities are arranged in a continuous row close to the endoderm; the upper are larger and more irregular in shape.

Disc and Tentacles.—The ectoderm and endoderm of the disc and tentacles are both crowded with zooxanthellæ. The mesoglœa of the latter is very thin, and the ectodermal muscular layer is well developed, in marked contrast to the endodermal. Cell-inclosures are found in the mesoglœa of the disc. The surface of the mesoglœa adjacent to the endodermal aspect is much plaited.

Œsophagus.—The œsophagus is oval in section, with a well-marked rectangular œsophageal groove. The ectoderm is very deeply folded into eight ridges along each side, the mesoglœa passing into each. The nuclei of the ectodermal cells form a well-defined and continuous central row. The mesoglœa is very thin, except at the groove, where it becomes somewhat thickened. As in *G. isolata* and *G. rusei* the mesoglœa has enclosures of granular cells placed more particularly at the insertion of the mesenteries, and at the bases of the outgrowths into the œsophageal folds.

Mesenteries.—The mesenteries show the brachycnemic arrangement in a very clear manner. There are twelve pairs of perfect mesenteries. The mesoglœa is very thin in the lower part. The musculature is relatively well shown on both perfect and imperfect mesenteries. The basal canals are large and rounded, especially in the region below the œsophagus; in the œsophageal region they become oval in section, and soon divide into two or more branches. Towards the top of the mesenteries the canals are more irregular. The mesoglœa in this region becomes very much and deeply plaited, and the endoderm is crowded with zooxanthellæ.

Cœnosarc (Pl. viii., fig. 6).—The ectoderm and incrustations have the same character as in the body-wall. The mesoglœa is crowded with cell-islets, and contains numerous cœlenteric canals.

Gonads.—Both of the specimens examined contain ova.

Gemmaria Canariensis differs from the four previously described species of the genus in the following characters:—1. In having the capitular region swollen when contracted. 2. In the presence of a thick cœnosarc. McMurrich (1889, p. 65) is inclined to believe that the polyps of *G. isolata* may be connected by a thin continuous cœnosarc, but owing to the fact of the polyps being buried up to the tentacles in sand, he was not able to decide this. 3. In the incrustations being limited to the ectoderm and the outermost part of the mesoglœa.

It agrees with *G. mutuki* and *G. isolata*, and differs from *G. Macmurrichi* in having a continuous ectoderm, *i.e.* not broken up by strands of mesoglœa. It also differs from the latter, and agrees with the other three species in the presence of zooxanthellæ. The musculature of the mesenteries is only slightly developed in *G. Macmurrichi* and *G. mutuki*, while it is fairly well developed in our species. It agrees with *G. Macmurrichi* in having only a weak tentacular ectodermal musculature.

PALYTHOA, Lamouroux, 1816.

Palythoa Gregorii, n. sp.

(Pl. VII., fig. 3.)

Form.—Cœnenchyme not distinguishable from the walls of the polyps; each projects above the general surface of the cœnenchyme, leaving irregular linear polygonal depressions between them. The projecting portion of each contracted polyp has the form of a flattened dome with a small central circular depression. No distinct capitular ridges and furrows.

Colour.—Sandy.

Dimensions.—Average diameter of polyps, 6 mm. The thickness of the colony is very variable, and with it the length of the polyps; greatest height, 27 mm.; least height, 10 mm.

Locality.—Mombassa, East Africa, collected by Dr. J. W. Gregory, of the British Museum. Only one colony incrusting an irregular base of nullipores.

The species is named after its distinguished collector.

Body-wall.—The ectoderm, where present, is continuous, of considerable thickness, and covered with a cuticle; large yellow oval nematocysts occur, which clearly show the internal spiral thread, as well as a large number of narrow elongated nematocysts.

The mesoglœa is not very abundant, and contains numerous isolated cells; cell-islets and lacunæ of all sizes crowd the mesoglœa, and contain large yellow nematocysts and zooxanthellæ. The incrustations, which extend throughout the mesoglœa, consist of fairly large quartz sand grains, a few sponge spicules, somewhat more numerous in the retracted or distal portion of the polyps, and a very little calcareous matter.

The endoderm is entirely macerated away, leaving only numerous zooxanthellæ.

Sphincter muscle (Pl VIII., fig. 7).—The sphincter muscle is single, mesoglœal, and of a considerable length.

Disc and Tentacles.—The mesoglœa of the disc is very thick, crowded with cell-islets and incrustations.

Œsophagus.—The ectoderm is folded, the foldings being partially accompanied by processes of the mesoglœa. The œsophageal groove is well marked, the mesoglœa being here a little thickened. The ectodermal muscle is feebly developed. In the mesoglœa are numerous cells and cell-islets.

Mesenteries.—The whole internal structure of the polyps is very badly preserved. The endoderm is wholly macerated, leaving numerous zooxanthellæ; no musculature can be distinguished. In each of the mesenteries is a large basal canal extending the whole vertical length, and containing numerous large yellow nematocysts. Various other canals or sinuses are seen in transverse sections of the mesenteries.

Gonads.—No gonads present.

Palythoa liscia, n. sp.

(Pl. VII., fig. 4.)

Form.—Contracted polyps not projecting, or but very slightly so, above the surface of the cœnenchyme. The upper surface of the colony is consequently very uniform, and the boundary between the individuals is not well marked; the polyps are irregularly arranged, but not crowded; each polyp has about fifteen capitular ridges and furrows. The colonies are very low and flat, the margins tending to incrust the objects upon which they grow.

Colour.—Sandy.

Dimensions.—Average diameter of contracted polyps at surface, 5 mm.; average thickness of colonies, 10 mm.

Locality.—Mombassa, East Africa, collected by Dr. J. W. Gregory, of the British Museum. Three colonies incrusting and almost surrounding an irregular base of nullipores.

The specific name has reference to the smooth appearance of a colony when in alcohol.

Body-wall.—The ectoderm covering the peripheral surface of the colonies has almost entirely disappeared. The mesoglœa uniting all the polyps in the colony is rather thicker than in *P. gregorii*, but isolated cells, cell-islets, and lacunæ, of all sizes, similarly crowd the mesoglœa; the islets and lacunæ contain the large yellow nematocysts and zooxanthellæ. The incrustations are of the same nature as those of the former species, principally coarse sand grains, but the distal portion of the polyps do not appear to have so many sponge spicules. The incrustations extend throughout the mesoglœa.

The endoderm is very uniform and thin, and crowded with zooxanthellæ. A weak diffuse endodermal muscle can be distinguished.

Sphincter muscle.—The single mesoglœal sphincter muscle extends for a considerable distance.

Disc and Tentacles.—The ectoderm of the disc is rather thick, crowded with zooxanthellæ and pigment particles, and that of the tentacles is crowded with long narrow nematocysts; the mesoglœa is thin, with incrustations and cell-islets; the endoderm is thin and crowded with zooxanthellæ.

Œsophagus.—The ectoderm of the œsophagus is folded, a well-marked groove occurs; large yellow oval nematocysts and narrow elongated ones are abundant. The mesoglœa is thin, but thickens a little at the œsophageal groove; it does not follow the foldings of the ectoderm; cell-islets occur in it.

Mesenteries.—These show the brachycnemic character well. The reflected ectoderm is well developed; below the œsophagus the mesenterial filaments or craspeda are large, and, like the ectoderm of the œsophagus, are crowded with the two kinds of nematocysts. The mesoglœa is very thin, except where it is perforated by the large basal canal; this contains large nematocysts. Smaller canals or sinuses also occur in the mesoglœa. The endoderm has numerous zooxanthellæ, and slight parieto-basilar muscles occur, and a very slight retractor muscle.

Gonads.—None present in any of the polyps examined.

It is extremely difficult to define the species of this genus, as we do not yet know what variations may take place in a given species owing to difference of environment.

Turning to the forms from the Indian Ocean, we have *P. tuberculosa* (Esper) *fide* Klunz., 1877; *P. flavo-viridis* and *P. argus*, Ehr., 1834, all from the Red Sea. Klunzinger states the two latter are synonyms of the species which he describes and which he allocates to Esper's *Alcyonium tuberculosum.* Esper (Der Pflanzenthiere, III. Alcyonium, p. 68) gave the name of *Alcyonium tuberculosum* to a Palythoa, from "Trankenbar" (probably Trankuebar, lat. 11° N., on the east coast of India), which he thought was the same as the *A. papillosum* of Pallas, from an unknown locality. His figure (Pl. XXIII., fig. 1) of the upper surface of the colony is not satisfactory, and does not agree with his description of the polyps growing thickly together, forming wart-like elevations of unequal size.

Hertwig investigated a specimen collected by the "Challenger," at Simon's Bay, Cape of Good Hope, and this he identified with Klunzinger's form. We speak with all caution and deference, but we venture for the present to uphold the doubt cast by one of us on this identification (Trans. R.D.S., 1891, p. 631). The very close opposition of the polyps, resulting in the markedly polygonal outlines of their contours appears to us to be very different from Klunzinger's species, and we therefore would propose the name of *P. capensis* for this form.

We have had considerable difficulty in deciding (1) whether our forms were to be regarded as belonging to one or two species, and (2) having provisionally decided in favour of the latter alternative, whether either was a new species or not. As the polyps are not distinctly polygonal in contour, we do not think either of our forms is *P. capensis.* We have carefully compared our specimens with Klunzinger's description, and find many points of resemblance and a few differences, the most important, perhaps, being that, in the latter, the polyps are less crowded. On the whole, then, we have decided to erect two new species, and so we must leave them till the group can be thoroughly investigated.

A list of the other species of this genus will be found on p. 631 of the "Revision of the British Actiniæ, II. The Zoantheæ." Dr. G. Müller (1883) described the following species:—*P. tuberculosa,* Klunz. (Red Sea), P. sp. (Phœnix Island, Pacific Ocean, about lat. 5 S., long. 175 W.); *P. calcaria,* n. sp. (Fiji "Viti"), P. sp. (Samoa), P. sp. (Rolas Island, Gulf of Guinea*), P. sp. (Rolas), P. sp. (Rolas); unfortunately he does not give any figures.

The available information about this peculiarly difficult genus is at present too slight for us to profitably enter at length into a comparison of the various species. Judging from the figure given in the atlas (pl. xiii., figs. 13, 14), neither of our species is *P. lutea,* Q. and G. (Tongatabu), as in the latter the polyps are more scattered. They also appear to differ from *P. aggregata,* Lesson (Society Archipelago), and *P. cœsia,* Dana (Fiji). Studer (1878, p. 547), without describing or figuring a species he collected at New Ireland, recorded it as *P. tuberculosa,* Esp. s. Klunz. They differ from *P. Kochii,* Hadd. and Shackl. (Torres Straits), by the incrustations being distributed throughout the mesoglœa, and not in a layer; the lacunæ and cell-islets are much more numerous; the the polyps project less, and there are only 15 capitular ridges instead of 20. In *P. Howesii,* H. and S. (Torres Straits), the polyps project more on one side; their diameter is 7 mm.; the mesoglœa of the œsophageal groove is thickened, and the incrustations are calcareous. They differ from *P. cœsia* (?), Dana (Torres Straits), by the smaller diameter (5 mm. instead of 9 mm.) of the polyps, their greater crowding, and, in the latter the endoderm is thrown into ridges. These three species are figured on Pl. LXI., Trans. R.D.S., IV., 1891.

It is improbable that any of the West Indian species occur in the Indian Ocean, and, on other grounds, we may dismiss those forms.

In his recently published paper ("Grundzüge der marinen Tiergeographie" Jena, 1896), Dr. A. E. Ortmann recognises the distinctiveness of the "Indo-pacific

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* We cannot identify this island.

littoral region" from the "East American littoral region" (which includes the West Indies), and also from the "Guinea sub-region" of the "West African littoral region." Dr. Ortmann allocates the littoral fauna of Cape Colony to the "Antarctic littoral region," which, in this case, separates the littoral fauna of East Africa from that of West Africa.

MACROCNEMINÆ.

EPIZOANTHUS, Gray, 1867.

Epizoanthus egeriæ, n. sp.

(Pl. VII., fig. 5.)

Form.—Polyps scattered. The column is short, rising very little in the contracted condition above the cœnosarc, encrusted with foraminifera, which give it a granular appearance. Upper surface of contracted column with from 12 to 18 wedge-shaped radial ridges; mouth aperture open in most.

Cœnosarc thin, incrusting, continuous, of the same nature as the wall of the column.

Colour.—The natural colour is removed by alcohol, leaving them a pale grayish buff.

Dimensions—Height, 1–2 mm. above the surface of the cœnosarc; average diameter 5 mm.

Locality.—Macclesfield Bank, about mid-way between Cochin China and Luzon, in the South China Sea. Depth 45 to 47 fathoms; dredged by H. M. S. "Egeria"; collected by P. W. Bassett-Smith, Surgeon, R.N.

There are two colonies, each incrusting almost the entire surface of two shells of *Murex tenuispina.* The cœnosarc also passes in and incrusts for some distance the mouth of the shells. In the larger specimen the polyps are more crowded on the oral aspect of the shell and along the varices.

Commensal with hermit-crabs.

Body-wall.—The ectoderm is continuous, except where interrupted by the incrustations. It is covered by a thin cuticle, upon which diatoms are very abundant. Large dark-brown oval nematocysts are numerous in some parts. Four polyps were sectionised for study, and the extent to which these dark nematocysts occur varies much in the different individuals.

The incrustations are very abundant, and consist largely of foraminifera and other calcareous material. A few siliceous sponge spicules occur. Owing to the incrustations, the boundary between the ectoderm and mesoglœa is very irregular.

The mesoglœa below the œsophageal region is not much thicker than the ectoderm, but in that region it thickens considerably. It is irregular in appearance, due to the numerous incrustations. Small cell-islets occur, but not abundantly. The endodermal muscular layer is but feebly developed.

The endoderm is narrow and the cells uniform in height.

Sphincter muscle (Pl. VIII., fig. 8).—The sphincter muscle is mesoglœal and single. It is well developed. At its distal and thickest part, the irregular cavities extend almost across the whole diameter of the mesoglœa, but lower down the spaces gradually become smaller. The muscle fibres are thin, and the cavities hollow.

Disc and Tentacles.—The large dark-coloured nematocysts occur in the ectoderm of the tentacles along with vast quantities of another smaller form. The ectodermal circular muscle is well developed on the plaitings of the mesoglœa. The endodermal muscle is only feebly developed. The endoderm is well developed.

Œsophagus.—The ectoderm of the œsophagus is almost smooth, not being thrown into well-marked folds. The groove is well developed, and the mesoglœa thickened in that region.

Mesenteries.—The arrangement of the mesenteries is macrocnemic. Owing to the fact that all the four specimens cut contain well-developed ova, this arrangement is not always easy to discern. Only in one or two instances can any trace of the imperfect mesenteries be seen.

Gonads—All the four individuals examined contained only ova.

It is characteristic of certain species of Epizoanthus to be commensal with hermit-crabs, and the carcinæcia which are thus formed may simply incrust the shell of the Gastropod, or they may actually replace it with their own cœnenchyme.

Our species may be readily distinguished from the others which form carcinæcia, as the polyps are numerous on the oral aspect of the Gastropod (Murex) shell; in other species of Epizoanthus that aspect is either bare of polyps (*E. incrustatus*, D. & K., *E. cancrisocius*, v. Mart., *cf.* Studer, &c.), or with one ventral polyp, and the remainder marginal (*E. paguriphilus*, Verr., *E. parasiticus*, Hertw.—probably not of Verrill, &c.).

PROTACTINIÆ (McMurrich, 1891) = PROTANTHEÆ (Carlgren, 1891).

CORALLIMORPHIDÆ (Hert., 1882). CORYNACTIDÆ (Andres, 1883).

CORYNACTIS (Allman, 1846).

Corynactis Australis, n. sp.

(Pl. VII., figs. 6–10.)

Form.—As is characteristic of other species of this genus, the form is very variable. Usually salver-shaped when fully expanded, the base may extend beyond the disc, or *vice versâ*; when the disc is not fully expanded, the column may be club-shaped or nearly cylindrical. We are unable to determine the arrangement of the tentacles either from the drawings or the specimens themselves. Those of the peripheral row are the longest, and there are three or four distinct rows decreasing in length centripetally. The small radial tentacles do not appear to have any definite arrangement. Mouth on a prominent cone.

Colour.—Very variable. Column pink, buff, brown, or orange, or of intermediate tints, sometimes with a greenish tinge. A green ring round the capitulum is often present; the ring may be yellow in colour, or apparently absent. Disc usually of a darker shade than the column, but may be bright green. Mouth generally greyish. Tentacles, stem usually greyish green or dark brown, occasionally translucent white or pink; knobs mostly bright orange, but may be translucent white, pink, or green.

Some of the combinations which may occur are detailed in the following list:—

	Column.	*Capitulum.*	*Disc.*	*Tentacles stem.*	*Knob.*
A.	Greenish.	Emerald green.	Bright green.	Pale carmine.	Pale carmine.
B.	Pink.	Emerald green.	Pinkish.	Pale green.	Pale carmine.
C.	Pale carmine.	White?	Pink.	Grey.	Orange.
D.	Pale orange buff.		Bright orange buff.	Grey.	Bright orange.
E.	Brown.	Brown.	Dark brown.	Brown.	Orange.
F.	Translucent pink.	Pale green.	Orange buff.	Brown.	Pink.
G.	Pinkish orange.	Lemon yellow.	Orange pink.	Translucent white.	Pink.

Dimensions.—Average height of column in living specimens, 8·5 mm.; average diameter of oral disc, 9 mm., according to Prof. Spencer's drawings.

Locality.—Port Philip, February 2nd, 1891; January 27th, 28th; February 3rd, 1892.

Body-wall (Pl. VIII., fig. 9).—The ectoderm is regular in structure. In some places it is considerably folded, but some of this is probably due to unequal contraction. The contents of the columnar cells do not stain deeply. The small nuclei appear in sections more as a band towards the inner end of the cells. The diffuse ectodermal muscle layer is clearly seen.

The mesoglœa in the upper part is thicker than the ectoderm, but it thins considerably towards the base of the column. In some cases it follows the folding of the ectoderm. It is almost homogeneous in structure, but a few small elongated cells may be observed.

The endoderm is a little thinner than the ectoderm, and is not thrown into ridges between any of the mesenteries. Highly refractive, club-shaped, glandular cells are present. A diffuse muscle is developed; towards the capitular region, it forms the endodermal sphincter muscle.

Sphincter muscle (Pl. VIII., fig.10).—The mesoglœa is thrown into slight folds in the region of the diffuse endodermal sphincter, which, except for the greater development of the muscle fibres, is scarcely distinguishable from the general endodermal muscle of the body-wall.

Tentacles.—The ectoderm of the tentacles consists mainly of columnar cells similar to those of the body-wall, but the contents stain more deeply. A few deeply-staining, large, oval nematocysts, with a spiral thread inside, occur. Towards the distal end, long, very narrow, yellowish nematocysts are abundant, and show a spiral thread. The highly refractive glandular cells of the endoderm also occur in the more proximal parts. The ectodermal muscular layer is well developed. The mesoglœa is much folded. The endoderm is about the same thickness as that of the column, and has also numerous glandular cells; a slight endodermal muscle occurs.

Disc.—The disc is much like the body-wall in structure; large oval nematocysts occur, and glandular cells are present in both ectoderm and endoderm.

Œsophagus.—The ectoderm of the œsophagus is much folded, and stains more deeply than that of the column; large oval nematocysts are present. The mesoglœa is thin, and follows the folds of the ectoderm. An œsophageal groove is not distinct.

Mesenteries.—The mesenteries consist of numerous pairs without, however, any apparent regular arrangement. Some specimens show only one pair of directives, while another shows two pairs. The arrangement and number of the pairs of perfect and imperfect mesenteries on each side of these is irregular.

The endoderm of the mesenteries is rather thick, and is made up of large columnar cells and numerous glandular cells. The retractor muscle is well developed, and the mesoglœa is thrown into broad folds for its support. The parieto-basilar muscles are well shown. Large oval nematocysts are abundant in some of the mesenterial filaments, but do not stain.

The mesoglœa varies considerably in thickness; towards the body-wall it is quite thick (Pl. VIII., fig. 9), but afterwards thins suddenly, becoming quite linear in section.

The irregularity in the arrangement of the mesenteries will be apparent when the enumerations of the following three specimens are compared together:—

(*a*). D. *1*, 2, *3*, 4, *5*, 6, *7*, 8, *9*, 10, *11*, 12, *13*, 14, *15*, 16, *17*.
(*b*). D. 1, 2, *3*, 4, 5, 6, 7, 8, 9, *10*, 11, 12, 13, *14*, *15*, 16, *17*, *18*, *19*, 20, *21*, 22, *23*, 24, *25*, 26, 27.
(*c*). D. 1, 2, *3*, 4, 5, 6, 7, 8, 9, *10*, D, *11*, 12, *13*, 14, *15*, *16*, 17, *18*.

The first is a young specimen in which the mesenteries are uniformly long and short. In the first two there is only one pair of directive mesenteries; whereas, in the last there are two pairs: in all cases the short mesenteries are indicated by *italic figures.*

Gonads.—Female gonads were present in only one specimen.

No detailed anatomical account of any member of this genus has as yet been published, but one of us has made sections of the type species *C. viridis*, Allm., and of *C. hoplites*, Hadd. and Shackl.

The new species differs from *C. viridis* in possessing a thick mesoglœa in the body-wall, and in the very thick proximal portion of the mesoglœa of the mesenteries. The upper portion of the sphincter of *C. viridis** (Pl. VIII., fig. 11) projects inwards with thin simple mesoglœal plaitings; in other words, the lower part of the sphincter is feeble and diffuse, while the upper part is a simple circumscribed endodermal sphincter muscle.

In *C. hoplites* the sphincter is much more deeply folded than in our species, but the retractor muscle of the mesenteries is feebler.

Family, ALICIIDÆ.

Hexactiniæ with a large, flat, contractile base. Tentacles simple, cylindrical, and entacmæous. Column with simple or complex hollow processes or vesicles over the greater part of its surface, arranged mostly in vertical rows. No cinclides.

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* Since the above has gone to press, we find that Herr Casimir R. Kwietniewski has published a paper entitled "Revision der Actinien, welche von Herrn Prof. Studer auf der Reise der Korvette Gazelle um die Erde gesammelt wurden," *Jenaische Zeitschr.* xxx., p. 583. He figures the sphincter of *Corynactis carnosa* Studer (Monats. K. Akad. Wiss. Berlin, 1878, p. 542), and it will be seen that it differs from that of our species, but very closely resembles that of *C. viridis.* This appears to us to be sufficient evidence to regard our species as distinct from Prof. Studer's.

Sphincter muscle endodermal and diffuse, variable in amount of development. Perfect mesenteries few or numerous. No acontia.

We have quoted the definition of the family as drawn up by one of us;* it includes the genera Alicia, Cystiactis, Thaumactis, and probably Bunodeopsis.

We think that the present state of our knowledge warrants the following arrangement:—

Aliciidæ, Duerden, 1895.

Alicia, Johnson 1861.
- *A. mirabilis*, Johnson, 1861, Madeira.
- *A. Costæ* (Panc.), 1868, Mediterranean.
- *A. grandis* (Verr.), 1869, Panama.
- *A. pretiosa* (Dana), 1846, Fiji.
- *A. rhadina*, Hadd. & Shackl., 1893, Torres Straits.

Cystiactis, Milne-Edwards, 1857.
- *C. Eydouxi*, M. Edw., 1857, Chili.
- *C. Gaudichaudi*, M. Edw., 1857, Rio Janeiro.
- *C. Reynaudi*, M. Edw., 1857, Cape of Good Hope.
- *C. tuberculosa* (Quoy & Gaim.), 1833, Bass Straits.
- *C. Eugenia*, Duch. & Mich., 1866, West Indies.

Thaumactis, Fowler, 1889.
- *T. medusoides*, Fowl., 1889, Papeete.

Bunodeopsis, Andres, 1880.
- *B. strumosa*, Andr., 1880, Bay of Naples.

ALICIA.

The genus Alicia has been re-defined as follows in the paper just referred to:—

"Tissues very delicate. Tentacles elongated, more or less retractile. Column with the distal vesicles pedunculated and much divided, the proximal vesicles simpler and more or less sessile. Sphincter muscle feebly developed. Mesenteries not very numerous; two pairs of directive mesenteries."

CYSTIACTIS.

Column covered with simple vesicles. Tentacles of variable length in one, two, or three cycles. Numerous perfect mesenteries. Sphincter muscle moderately well developed.

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* J. E. Duerden, "On the Genus Alicia (Cladactis), with an Anatomical Description of *A. costæ*, Panc., Ann. Mag. Nat. Hist. (6), xv. 1895, p. 213.

The genus Cystiactis was thus defined by its author, Milne Edwards:—"Body entirely covered with subtentaculiform tubercles, or presenting an appearance of large, very prominent vesicles." He erected the genus to include three species of Actiniaria, preserved in the Paris Museum of Natural History. These species were:—

1. *Cystiactis Eydouxi.*—Tentacles thick-set, moderately numerous, longitudinally striated by contraction; the external smaller than the internal. Body covered with large vesicles of very unequal size, very crowded and irregularly arranged. Of a uniform brown colour in alcohol. Coasts of Chili (Eydoux).

2. *Cystiactis Gaudichaudi.*—Tentacles longer and more slender than in *C. eydouxi;* vesicular tubercles of the body smaller, sub-serial, and often presenting at the summit a kind of rosette formed by blackish spots [the last character rather suggests that this species will ultimately be transferred to the genus Alicia]. Blackish in alcohol. Rio Janeiro (Gaudichaud).

3. *Cystiactis Reynaudi.*—Tentacles shorter than in *C. Eydouxi* and *C. Gaudichaudi.* Tubercles in the form of crowded vesicles, sub-serial, and of a medium size. Clear brown colour in alcohol. Cape of Good Hope (Reynaud).

This genus was adopted by Duchassaing and Michelotti, who described a new species, *C. Eugenia.* Mem. R. Accad. Sci. Torino, XXIII., 1866, p. 129, pl. vi., fig. 1. This has a cylindrical column, with club-shaped vesicular tubercles. Tentacles few (about 20), sub-equal, cylindrical, pointed, long, delicate, translucent. Peristome prominent. Of small size, and swimming freely or adherent to floating objects.

In his Monograph, Andres (p. 228) admits only the last as belonging unquestionably to this genus, and places the species described by Milne-Edwards amongst his "*Bunodide dubiæ*" (p. 236), as they are insufficiently characterised and figures are wanting. He adds:—"The form of the column reminds one of Bunodeopsis."

Milne-Edwards places Cystiactis amongst his "*Actinines verruqueuses,*" and Andres puts them in the sub-family, Bunodidæ. When we investigated *Cystiactis tuberculosa* (Q. & G.), we found that it would have to be removed from that group; and since then one of us has examined an allied form *Alicia Costæ* (Panc), and the new family Aliciide was proposed to include these two genera.

Judging from the figure (Atlas, pl. iii., fig. 19) it is possible that *A. monilifera* Dana (U. S. Expl. Exp.) may belong to this genus.

Our definition of the genus is based upon an examination of *C. tuberculosa*, and may have to be emended when the type species is rediscovered and properly described.

Cystiactis tuberculosa (Quoy & Gaim.).

(Pl. vii., fig. 11.)

Actinia tuberculosa (*A. tuberculeuse*),	Quoy & Gaimard, "Zool. Voy. de l'Astrolabe" (Dumont d'Urville), 1833, iv., p. 159, pl. xi., figs. 3–6.
,, ,,	Blainville, 1834, "Man. d'Act.," p. 319.
Cereus? tuberculosus, ...	Milne-Edwards, "Hist. nat. des Coral.," 1857, i., p. 268.
(gen. nov.?) *tuberculosa*, . .	Andres, 1884, "Die Actinien," p. 231.
Cystiactis tuberculosa, . . .	Duerden, 1895, Ann. Mag. Nat. Hist. (6), xv., p. 213.

Form.—A large thin-walled Actinian, when fully expanded nearly as broad as high. Column crowded with large, delicate, oval vesicles, the cavities of which communicate with the cœlenteron. Tentacles numerous, of moderate length, in three or four rows. Oral disc apparently of not much greater diameter than the column. Mouth large, circular. Pedal disc of greater diameter than the column, somewhat inflated. The figure is reconstructed from several slight sketches made by Prof. Spencer.

Colour.—Upper part of pedal disc dark-grey, with light lines for the mesenteries. The pedal disc itself is of a deep chrome-yellow or orange, becoming paler or yellowish-green towards the centre, the mesenteries showing as bluish-grey lines. Vesicles either deep chrome-yellow with bluish vertical stripes, or bluish-grey with light stripes. Tentacles yellow, orange, or bluish, usually yellowish at base, then often brownish, with a yellow tip; the chrome-yellow of the tentacles has not such a red tinge as that of the vesicles; space between tentacles grey. Oral disc yellowish, passing into orange (or even dark grey) round mouth. Inside of mouth grey.

Dimensions.—About 6 inches (150 mm.) in height, 5 inches (125 mm.) in width, largest tentacle 1 inch (25 mm.) in length. Vesicles may be fully 1 inch (25 mm.) long, and $\frac{1}{2}$ inch (13 mm.) wide.

Locality.—Coogie, New South Wales.

As our description of this species is drawn up from the sketches and coloured details sent to us by Prof. Baldwin Spencer, and from spirit specimens, we think it advisable to reprint Quoy and Gaimard's original description, which supplements our own:—

"*Actinie tuberculeuse*, *Actinia tuberculosa*, nob.—Actinia, turriculata, molle, subrubra, tuberculis ovalibus, striatis, ordinatis, ornata; tentaculis brevibus, subluteis; ore rubenti.

"This species is remarkable for its straight sides, resembling a tower, although it is very soft; by the number of smooth, oval tubercles which cover it in vertical rows, which are sometimes very regular. These excrescences, which almost touch one another, vary in colour; they are reddish-brown, or golden, or of a dull crimson, or brownish, but always longitudinally marked with two or three bands of a deeper colour. But what only varies rarely is that there are six vertical rows of tubercles of a pretty bluish-grey, lined with brown. The disc, of a delicate yellow, bears three rows of short tentacles, and tinted with the same colour. The margin of the mouth is orange.

"This Actinian is a wanderer, or adheres only very slightly to the ground, for each tide throws up millions on the shore. Those we found at King George's Port (Port du Roi-Georges) were only about two inches in diameter; but further away, at Western, in Bass' Straits, individuals had the size of two fists."

Body-wall.—The ectoderm (which has almost entirely disappeared in the specimens) is of medium thickness, and covered with a delicate cuticle, in which is imbedded foreign colourless particles.

The mesoglœa presents a granular appearance, due to the number of very small cells. Its inner border is much plaited for the endodermal muscle.

The endoderm is thick and crowded with dark granules; the dark granules which occur so numerously in the endoderm are probably the remains of Zooxanthellæ. The muscle layer is well developed and slightly dendritic in section; it is especially well marked around the apertures communicating with the vesicles. The latter have the same structure as the body-wall. The mesoglœa is very thin.

Sphincter muscle (Pl. IX., fig. 1).—The sphincter muscle is elongated and diffuse, and extends vertically from the outermost tentacle to the uppermost vesicles. The muscle fibres are rather weak, and are disposed on mesoglœal folds, which are sometimes complex.

Tentacles (Pl. IX., fig. 2).—Ectoderm thick. The muscle is very strongly developed, and has become mesoglœal in position. The mesoglœa is thick. The endoderm is thick and crowded with granules. The endodermal muscle is distinct.

Disc.—No ectoderm is preserved. The mesoglœa is of medium thickness, and much plaited for the support of the endodermal muscle. Endoderm thick and crowded with granules.

Œsophagus.—With twenty or more folds on each side. The ectodermal folds are supported by mesoglœal extensions. Ectoderm, with elongated mesoglœa, thin. Endoderm as in disc.

Mesenteries (Pl. IX., fig. 3).—Very numerous. They appear to be arranged in the ordinary Hexactinian manner, and to consist of 5 cycles (6 + 6 + 12 + 24 + 48). No directive mesenteries were observed.

Endoderm regular; well developed parieto-basilar muscles on each side. On the side opposite to the retractor muscle is a special outgrowth of mesoglœa ("pennon") for the basal muscle of that side. Retractor muscles well developed on numerous deep plaitings of the mesoglœa; those are often slightly complex. Mesoglœa fairly thick in muscular region.

Mesenterial filaments well developed, with abundant narrow nematocysts. The mesenteries quite fill up the cœlenteron in the contracted spirit specimens.

Gonads.—Testes occurred in all three specimens.

THAUMACTIS.

Aliciidæ with irregularly scattered, complex vesicles, which when fully developed are prolonged into an elongated tubular process. Tentacles marginal; about twenty in number. Ectodermal muscle fibres in capitulum and œsophagus. Feeble, diffuse, endodermal sphincter. Two cycles of perfect mesenteries. No œsophageal groove.

We have drawn up the foregoing diagnosis, from the description by Dr. G. H. Fowler, of *Thaumactis medusoides*,* gen. sp. nn. The specimens at Dr. Fowler's disposal were very young, and strongly retracted forms. These circumstances, combined with the delicacy of the tissues and the flattening of the body, somewhat misled that investigator. Thus he has mistaken the vesiculated column for an "oral surface" bearing irregularly scattered "pseudo-tentacles." His "invaginated oral surface" is the capitulum. The mesenteries are apparently arranged on the Hexactinian plan, the irregularity noted by Dr. Fowler being probably due to immaturity. His largest specimen had paired mesenteries in three cycles; but those of the third cycle were imperfect in the sulculo-lateral exocœl. In one specimen there was only one pair of directive mesenteries, and in another none were present. We do not regard the ectodermal muscle of the capitulum and œsophagus as being of sufficient importance to warrant the creation of a new family for its occurrence; and the presence of a general ectodermal muscle enters into the diagnosis of the tribe as given by Carlgren.

From the foregoing description, it is evident that there is no need to place this form in a new tribe (Thaumactiniæ). Dr. Carlgren suggests that it might be placed as the representative of a new family (Thaumactinidæ) among his Protantheæ.

We have retained Dr. Fowler's genus on account of the formation of the vesicles and the ectodermal muscle. It is certainly a member of the family Aliciidæ.

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* "Two New Types of Actiniaria," Quart. Journ. Micr. Sci., XXIX., 1889, p. 143.

BUNODEOPSIS.

Until the sole representative of the genus Bunodeopsis, *B. strumosa*, has been anatomically investigated, we cannot be quite sure what it is. At all events it is probably very closely allied to the genus Cystiactis; and we may certainly adopt the opinion of Dr. Andres that it is quite distinct from *Alicia* (*Cladactis*) *costæ*. We therefore provisionally retain it among the Aliciidæ.

HEXACTINIÆ.

ANTHEADÆ (Hertwig, 1882).

ACTINIOIDES, Hadd. and Shackl., 1893.

Antheadæ with more or less prominent suckers on upper portion of column; capitular margin with conical acrorhagi. Diffuse or feebly circumscribed endodermal sphincter muscle.

We have added the character of the sphincter muscle to the original definition of this genus,* and have taken from it the statement that the acrorhagi "are provided with a well developed battery of nematocysts," as, though this is characteristic of the type species, *A. Dixoniana*, we do not find this detail sufficiently marked in our new species to warrant its being retained as a generic character.

Actinioides Spenceri, n. sp.

(Pl. VII., fig. 12.)

Form.—Column rather short and cylindrical with eighteen vertical rows of sucker-like verrucæ, of which the distal are the largest, and they gradually diminish inferiorly; capitulum with eighteen acrorhagi; tentacles short, blunt, in two cycles of eighteen in each cycle, the inner cycle being about one-half of the diameter of the disc in length, and about half as long again as the outer row. Oral disc of not much greater diameter than the column. Basal disc of not greater diameter than column.

Colour.—Column dull reddish-orange; the capitulum dark purplish-brown, which colour extends slightly down the lines of the verrucæ and shades off into the orange of the rest of the column; verrucæ white with a dark central spot; large inner tentacles orange with brown transverse bands (on their oral aspect);

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* Proc. Roy. Dub. Soc., VIII. (N.S.), 1893, p. 126.

outer row dark brown; disc blotched with brown; margin of mouth light-yellow; œsophagus pinkish.

Dimensions.—According to the coloured drawing sent to us by Professor Spencer, the diameter of the column would be about 35 mm., and its height about 25 mm.

Locality.—Port Philip.

The single specimen we received was in a contracted condition.

Body-wall (Pl. IX., figs. 4, 5).—Thin; ectoderm broader than mosoglœa, regular, with numerous small nuclei; no cuticle present; weak muscle. Mesoglœa thin, with small cells. Endoderm thinner than the mesoglœa, regular, crowded with dark granules; muscle weak.

Acrorhagi (Pl. IX., fig. 4.).—Ectoderm much as in body-wall, with numerous nematocysts; mesoglœa thinner than in body-wall. The acrorhagi are circumscribed externally by a distinct sphincter which projects into the cavity of the stem, and which is provided with simple mesoglœal plaitings, mainly on the inferior aspect of the projection.

Sphincter muscle.—The small, diffuse, endodermal muscle is situated near the base of the acrorhagi on their oral aspect; the plaitings of the mesoglœa are mostly simple, though a few are very slightly complex.

Tentacles.—Ectoderm very thick, crowded with extremely small colourless curved nematocysts; muscle well developed on plaitings of the mesoglœa. Mesoglœa thin. Endoderm thick, and crowded with dark granules.

Mesenteries (Pl. IX., fig. 5).—Twelve pairs of perfect mesenteries, of which two pairs are directives. In the lower part of the column twelve pairs of small imperfect mesenteries alternate with these. The perfect mesenteries bear the gonads, which in this specimen were ova. The parieto-basilar muscles are well developed on simple plaitings of the mesoglœa; on the side opposite to the retractor muscle is a thin pennon. The retractor muscle is strongly developed, and appears as an elongated half-oval in section; the numerous long mesoglœal plaitings are simple and slightly branched. The mesoglœa is moderately thin. The mesenterial filaments are crowded with small thin nematocysts.

This species, while presenting an external similarity to *A. Dixoniana*, can be readily distinguished from that species both externally and anatomically; for example, the character of the sphincter is different in the two species, and the older species lacks the acrorhagial sphincter, while it possesses a distinct battery of nematocysts on those processes.

SAGARTIDÆ.

This family is still in need of a thorough revision, as only a few of its members have been thoroughly examined. The best work in this family has been done by Dr. Carlgren,[*] who recognises three sub-families (Sagartinæ, Metridinæ, and Phellinæ). We admit that the accounts of the following three species is very inadequate; but our material was very limited, and most of the members of this group are so very contractile that it is, as a rule, extremely difficult to study preserved examples.

We recognise that our three forms belong to two genera, the first, *S. Carlgreni*, evidently belongs to the Sagartinæ and probably to the genus Sagartia. The two other species, *M. Australiæ* and *M. similis*, are closely allied to one another; they may belong to the Metridinæ or to a new sub-family, and we think they should be placed in a new genus.

SAGARTIA (Gosse, 1855).

Sagartia Carlgreni, n. sp.

(Pl. VII., fig. 13.)

Form.—Column, elongated and cylindrical, smooth; pedal disc large, flat, sinuous margin; oral disc of not much greater diameter than the column. Tentacles, numerous, long, thin, subulate, apparently in three cycles. Mouth large.

Colour.—Column, pedal and oral disc bright deep-orange; tentacles, opaque. white for their proximal third, greenish-grey for their distal two-thirds.

Dimensions.—Judging from the coloured drawing, the height is about 20 mm., with an average diameter of about 10 mm. Tentacles about 10 mm. long. This specimen is probably not full-grown.

Locality.—Port Philip (January, 1892).

Two specimens were received. We give ourselves the pleasure of associating with this species the name of our distinguished Scandinavian colleague.

Body-wall.—The ectoderm is regular in structure, with a definite cuticle. Small oval nematocysts are very abundant in the upper part of the column. The basal muscle threads are clearly seen. The ectoderm is much folded in the contracted specimen. The mesoglœa in the latter is quite thick, and presents a granular appearance owing to the abundance of uniformly small granular cells The endoderm is regular and pretty thick, and its muscle is fairly well developed.

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[*] O. Carlgren, "Studien über Nordische Actinien," I. Kongl. Svenska Vet.-Akad. Hand. xxv., 1893.

Sphincter muscle (Pl. x., fig. 1).—The character of the mesoglœal muscle is best understood from the figure. The narrow elongated muscle-cavities are very characteristic, and give a striped appearance to the sphincter, which is more apparent in its lower half. It must be borne in mind that, at present, we are unable to say what variation in the appearance of sections of sphincter muscles may be attributed to different stages of contraction.

Mesenteries.—There are twelve pairs of perfect mesenteries, of which one pair are directives. The mesenterial formula is 6 + 6 + 12 + 24, the fourth cycle being rudimentary. The first, second, and third cycles are fertile (ova in this case). The character of the simple retractor muscles is shown in the figure (P. x., fig. 2).

MITACTIS, n. g.

Sagartians with a strong mesoglœal sphincter. A variable number, probably always more than six, of perfect mesenteries. One or two pairs of directive mesenteries. Body-wall without a membranous covering. Disc of not much greater diameter than the column. Tentacles short, conical in three or four cycles.

Future investigations will show whether we are justified in erecting this new genus; at present we think it desirable to separate these forms from other Sagartians. We have named the genus from μίτος, a thread, in reference to the acontia.

Mitactis Australiæ, n. sp.

(Pl. VII., fig. 14.)

Form.—Short, thick column, the height of which is about equal to the diameter of the oral and pedal discs, but it is somewhat narrower than them, evidently smooth and soft, and variable in shape. Tentacles sub-equal, short, thick, pointed, apparently tri-cyclic. Mouth small, rounded.

Colour.—Uniform translucent buff; tentacles more of an orange colour; insertions of mesenteries show as light lines; ovaries shine through the body-wall as orange-coloured masses.

Dimensions.—Height of column, 10 mm.; diameter of oral disc, 12 mm.; of column, 8 mm.; length of tentacles, 2 mm. These figures are reckoned from the coloured drawing, and we cannot guarantee their absolute accuracy.

Locality.—Port Philip.

Body-wall.—Ectoderm regular, with a well-defined cuticle, a nucleated basal layer, and a fine ectodermal basal muscle. Nematocysts are very numerous, some being elongated and darkly granular. Mesoglœa variable in thickness, owing to various degrees of contraction, thicker in upper part of column in the region of the sphincter muscle, containing minute branched cells. Endoderm generally half the thickness of the ectoderm. The basal muscle is well developed.

Sphincter muscle (Pl. x., fig. 3).—The sphincter muscle is well developed, and extends for a considerable distance. The cavities are not filled with muscle cells. Their character is seen in the figure.

Tentacles.—The ectoderm of the tentacles is crowded with small oval nematocysts, which, in some places, perhaps owing to the folding of the ectoderm, appear as if arranged in a pinnate manner. The nervous layer of the ectoderm is well marked, and the muscle is strongly developed. The endodermal muscle is extremely feebly developed.

Disc.—The histology of the disc resembles that of the tentacles, but the ectoderm is thinner, and the endodermal muscle is well developed.

Œsophagus.—Large and much folded, with appressed walls in section; ectoderm regular, not folded, with glandular cells, and long dark granular nematocysts.

Mesenteries.—We have found it impossible to accurately determine the arrangement of the mesenteries; but we think that the mesenteries are not in multiples of six, and that certain of the mesenteries which would correspond with the second cycle of a hexamerous form are perfect. The single pair of directives, so far as we can make out, are sterile, and the other primary mesenteries are also probably so; the second cycle appear to be fertile; the third cycle of mesenteries are imperfect and fertile; the fourth cycle are short and sterile.

The mesoglœa is thin; the character of the retractor muscles will be seen on reference to Pl. x., fig. 4.

Acontia are abundant and crowded with very long nematocysts.

Gonads.—The specimen examined was a female.

Mitactis similis, n. sp.

(Pl. VII., fig. 15.)

Form.—Short, thick column; oral and pedal discs somewhat wider than column; tentacles sub-equal, short, thick, blunt, in three or four cycles.

Colour.—Uniform deep orange, almost a terra-cotta tint; tentacles paler, a sort of flesh-colour.

Dimensions.—Height of column, about 16 mm.; diameter of oral disc, about 16 mm.; length of tentacles, 2 mm. These figures are only very approximate.

Locality.—Port Philip.

We have given this species its name from the fact that it appears to closely resemble the preceding species in its external characters.

Body-wall.—Ectoderm fairly thick, with a distinct cuticle; dark-coloured, granular nematocysts in upper part of the column; basal muscle weak. Mesoglœa thick, with numerous, very small branched cells, which give it a rather granular appearance. Endodermal muscle rather thick, and rising into a small ridge between the bases of the mesenteries.

Sphincter muscle (Pl. x., fig. 5).—The single elongated mesoglœal sphincter muscle lies towards the centripetal or endodermal aspect of the mesoglœa; the cavities are numerous and irregular, and their muscular lining is very thin. The muscles terminate inferiorly in very narrow, elongated spaces, which eventually merge into the muscular layer of the endoderm.

Tentacles.—The histology of the tentacles closely resembles that of the body-wall, but the mesoglœa is not so thick. The dark-coloured nematocysts are more numerous, and the ectoderm is also crowded with small colourless ones. The ectodermal and endodermal muscles are well developed.

Œsophagus.—The ectoderm of the œsophagus is thrown into deep folds, in which the mesoglœa is implicated. There is no œsophageal groove.

Mesenteries.—There are thirteen pairs of perfect mesenteries, two of which are directives; but these are irregularly disposed, as in the following formula:—13 (D. 7. D. 4.) + 13 + 26 = 52. The mesoglœa is very thick, and the plaitings of the retractor muscles are moderately complex. (Pl. x., fig. 6).

Externally this species is very like the last, at least judging from the sketches made by Professor Spencer. We think, however, that some of the anatomical details mentioned by us are sufficiently different to warrant us in regarding them as distinct species. We might recall the differences in the sphincter muscle, the more complex character of the retractor muscles of the mesenteries, and the thicker mesoglœa in *M. similis* as compared with *M. Australiæ.*

EXPLANATION OF PLATE VII.

PLATE VII.

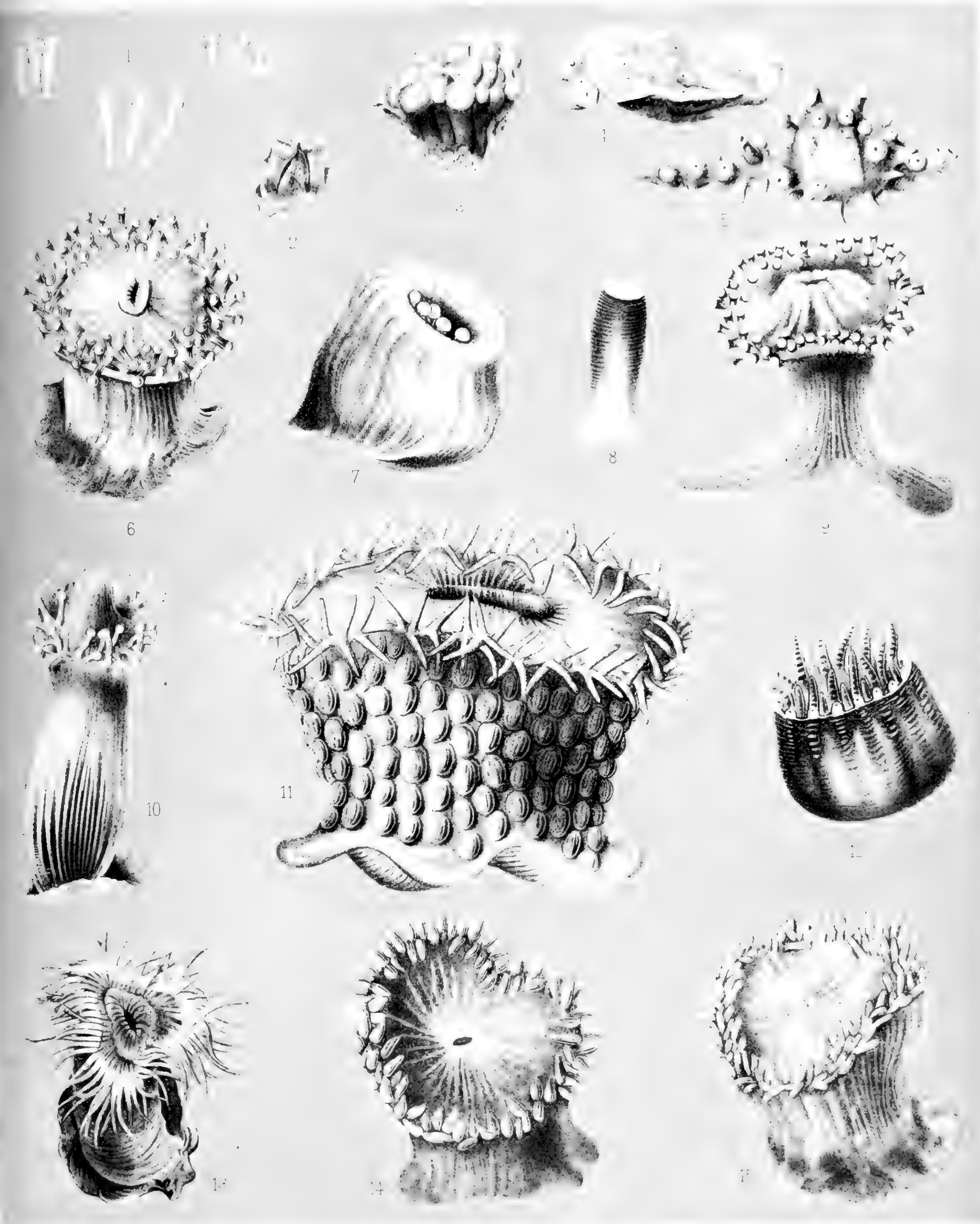
Figure
1. *Zoanthus Shackletoni*, n. sp., nat. size.
2. *Gemmaria Canariensis*, n. sp., nat. size.
3. *Palythoa Gregorii*, n. sp., nat. size.
4. *Palythoa liscia*, n. sp., nat. size.
5. *Epizoanthus egeriæ*, n. sp., nat. size.
6. *Corynactis Australis*, n. sp., × 4, specimen A.
7. ,, ,, × 4, specimen D.
8. ,, ,, fully expanded tentacle of fig. 9, greatly enlarged.
9. ,, ,, × 4, specimen F.
10. ,, ,, × 4, specimen C, fully extended.
11. *Cystiactis tuberculosa*, Q. et G.
12. *Actinioides Spenceri*, n. sp.
13. *Sagartia Carlgreni*, n. sp.
14. *Mitactis Australiæ*, n. sp., × $3\frac{1}{2}$.
15. *Mitactis similis*, n. sp., × $2\frac{1}{2}$.

Figs. 1–5 were drawn by Mr. Wilson from spirit specimens.

Figs. 6–15 are copies of coloured drawings and sketches made from the living polyps by Professor W. Baldwin Spencer.

Fig. 11 is a composite drawing made from several very rough outlines by Professor Spencer, and from some spirit specimens.

Plate VII



EXPLANATION OF PLATE VIII.

PLATE VIII.

LETTERING ON THE FIGURES.

b. c.	basal canal.	*end. sph.*	endodermal sphincter muscle.
	canals.	*gl.*	unicellular glands.
.i.	cell-islets.	*imp. mes.*	imperfect mesentery.
cœl. can.	cœlenteric canals.	*incr.*	incrustations.
cu	cuticle.	*m.*	mesoglœa.
	ectoderm.	*p. b. m.*	parieto-basilar muscle.
ect. m.	ectodermal muscle.	*sph.*	sphincter muscle.
end.	endoderm.	*s. cu.*	sub-cuticula.
end. m.	endodermal muscle.	*t.*	tentacle.

Zoanthus Shackletoni, n. sp.

Figure

1. Longitudinal section through the body-wall, showing the contorted subcuticula, × 70.
2. Vertical section through the sphincter muscle, showing the large proximal or lower sphincter, and the small distal or upper sphincter, × 35.
3. Transverse section through the proximal portion of a perfect mesentery to show the large basal canal, × 75.

Gemmaria Canariensis, n. sp.

4. Transverse section through a portion of the body-wall just below the level of the œsophagus, × 35.
5. Vertical section through the sphincter muscle, × 24.
6. Vertical section through the cœnosarc, × 24.

Palythoa Gregorii, n. sp.

7. Semi-diagrammatic vertical section through the sphincter muscle. Only the mesoglœa is represented in the figure, × 75.

Epizoanthus egeriæ, n. sp.

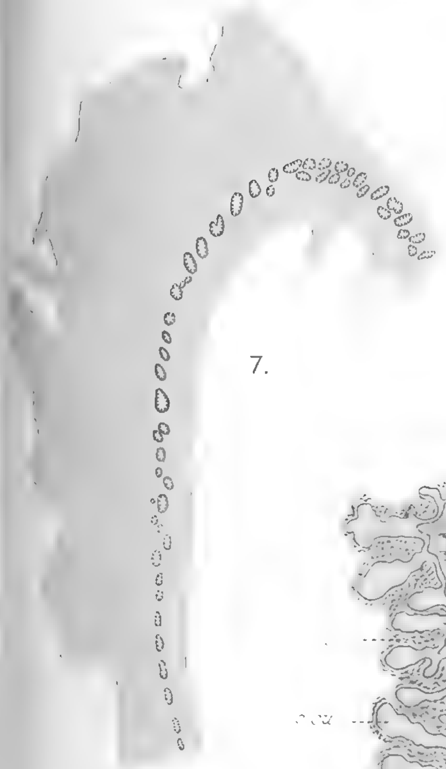
8. Vertical section through the sphincter muscle, × 24.

Corynactis Australis, n. sp.

9. Transverse section through the body-wall and the bases of two mesenteries, × 75.
10. Vertical section through the sphincter muscle, × 75.

[*Corynactis viridis*, Allman, West of Ireland.

11. Vertical section through the sphincter muscle of an expanded polyp.]



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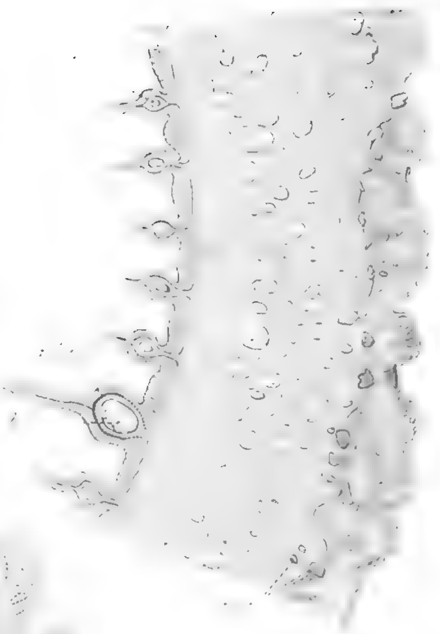

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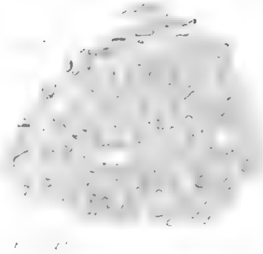

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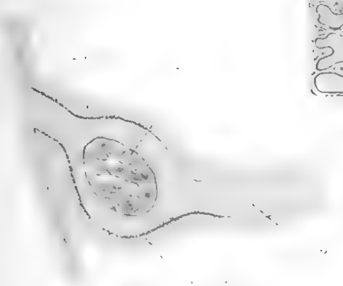

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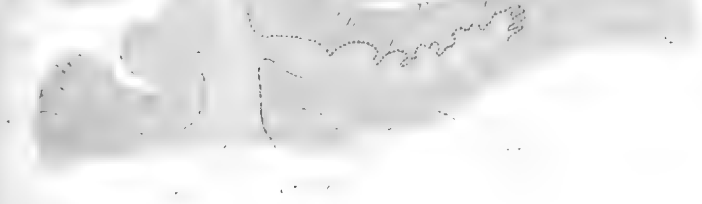

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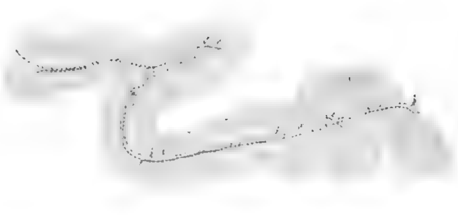

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EXPLANATION OF PLATE IX.

PLATE IX.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ect.	ectoderm.
end.	endoderm.
m.	mesoglœa.
ov.	ovum.
p. b. m.	parieto-basilar muscle.
p. m.	pennon muscle.
sph.	sphincter muscle.
t.	tentacle.
t.	testis in figure 3.
v.	vesicle.

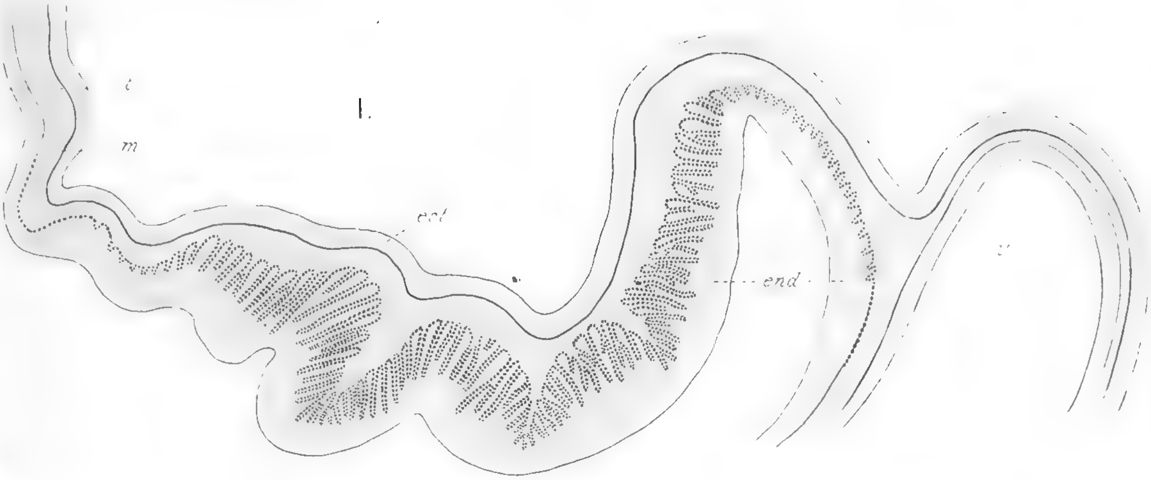
Cystiactis tuberculosa (Quoy et Gaim.).

Figure

1. Vertical section through sphincter muscle, × 75.
2. Transverse section through part of a tentacle, showing the ordinarily ectodermal muscle become mesoglœal in this species, × 75.
3. Transverse section of the proximal portion of a mesentery. Three mother cells of spermatozoa are seen, × 75.

Actinioides Spenceri, n. sp.

4. Vertical section through the acrorhagia of a contracted specimen, × 75.
5. Transverse section through the body-wall and proximal portion of a mesentery, × 75.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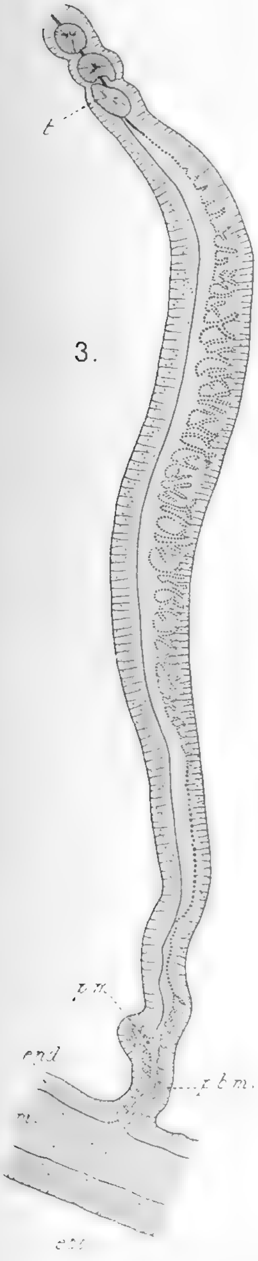
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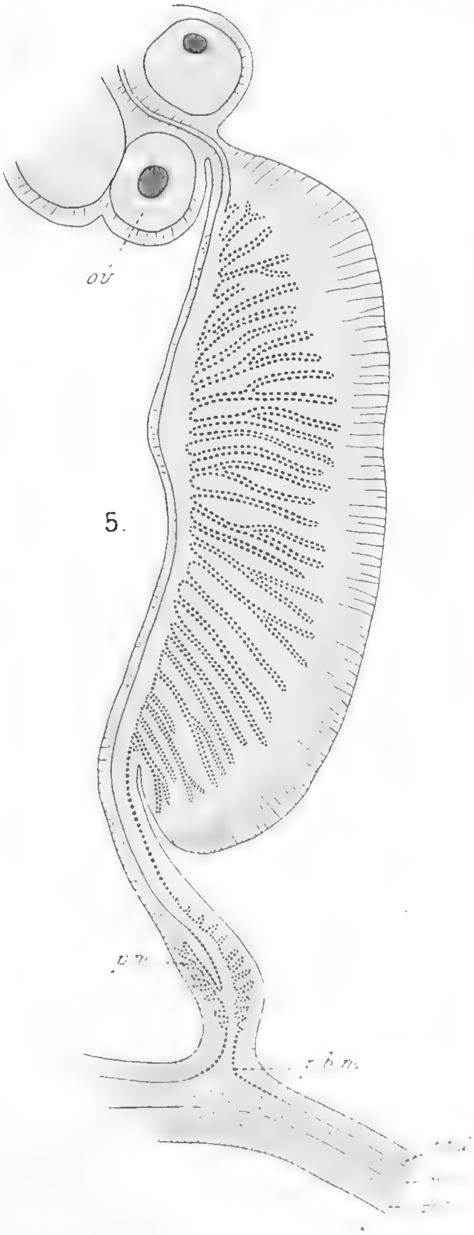
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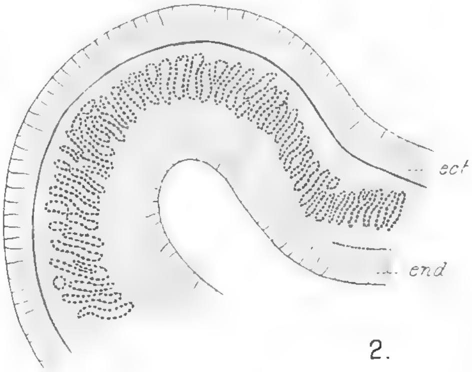
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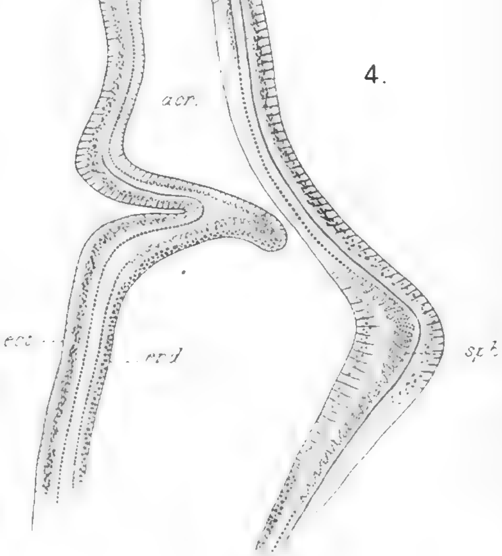
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EXPLANATION OF PLATE X.

PLATE X.

LETTERING ON THE FIGURES.

ect.	ectoderm.	*m.*	mesoglœa.
end.	endoderm.	*œs.*	œsophagus.

Sagartia Carlgreni, n. sp.

Figure

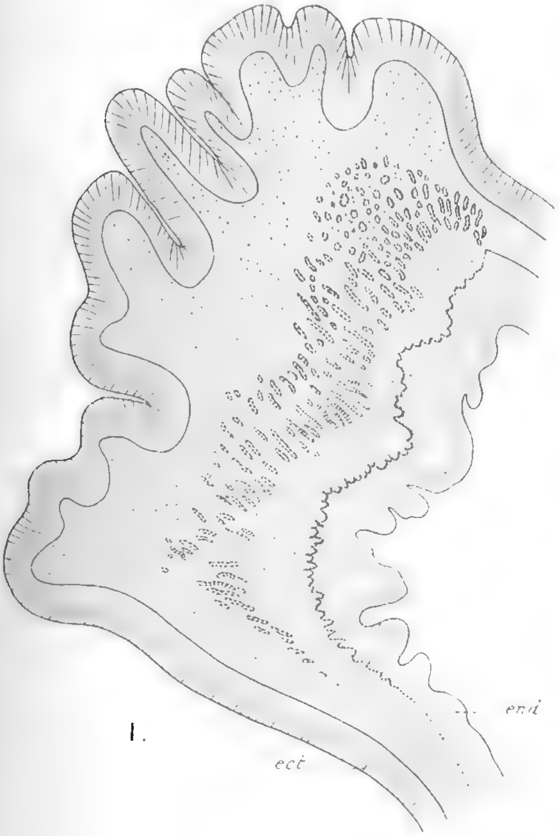
1. Vertical section through sphincter muscle of a considerably retracted specimen, × 75.
2. Transverse section through the body-wall and a mesentery in the œsophageal region, × 75.

Mitactis Australiæ, n. sp.

3. Vertical section through sphincter muscle, × 75.
4. Transverse section through the body-wall and a mesentery in the œsophageal region, × 75.

Mitactis similis, n. sp.

5. Vertical section through sphincter muscle, × 75.
6. Transverse section through the body-wall and a mesentery in the œsophageal region, × 75.



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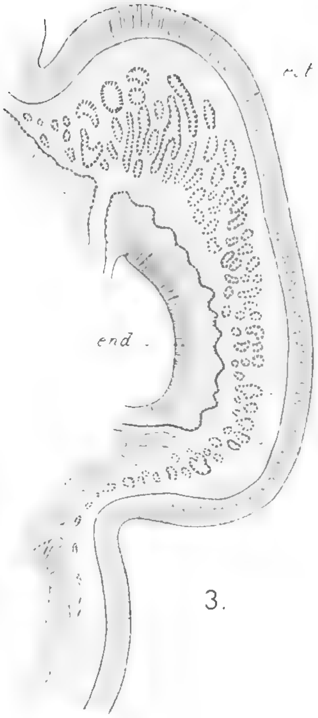

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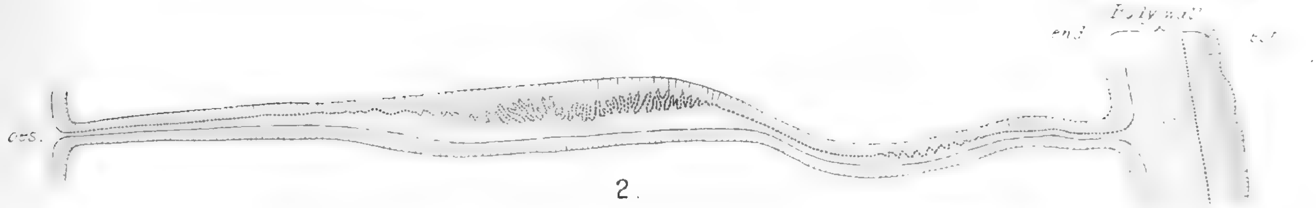

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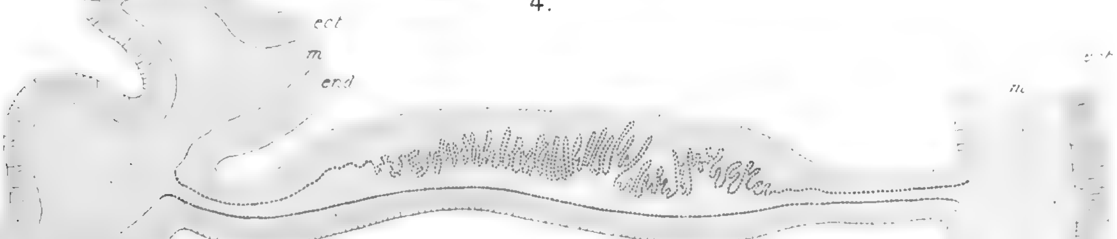

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VII.

ON CARBONIFEROUS OSTRACODA FROM IRELAND.

BY T. RUPERT JONES, F.R.S., AND JAMES W. KIRKBY.

(PLATES XI. AND XII.)

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ON CARBONIFEROUS OSTRACODA FROM IRELAND.

By T. RUPERT JONES, F.R.S., and JAMES W. KIRKBY.

(Plates XI. and XII.)

[COMMUNICATED BY PROFESSOR W. J. SOLLAS, LL.D., F.R.S.]

[Read March 18, 1896.]

Introduction.

In 1866, Messrs. Jones and Kirkby made a critical examination of all that had been published about the Carboniferous Entomostraca of Ireland.* Thirteen species were tabulated at p. 49, *op. cit.*, with their localities, according to indications given by Professor M'Coy in the "Journ. Geol. Society Dublin," vol. ii., 1839; and more especially in his "Synopsis of the Characters of the Mountain-limestone Fossils of Ireland," 1844. In determining these species Messrs. Jones and Kirkby had been favoured by Sir Richard Griffith with the opportunity of studying the specimens which Professor M'Coy had examined and named. Other specimens had been submitted to them for examination by the officers of the Geological Survey (see pages 48–51 of the same Memoir); but they mostly represented the same species as were enumerated in the Table at p. 49.

Of the Entomostraca alluded to above, the majority are Ostracoda of the Podocopa group, more or less allied to the Cytheridæ; only three or four belong to the group of the Myodocopa, namely Cypridinidæ and Entomoconchidæ.

In 1874, however, thirty-one of the latter great group were described and figured, as occurring in Ireland, in the "Monograph Brit. Foss. Biv. Entom. Carbonif. Formations," by Jones, Kirkby, and Brady, pt. i., Palæont. Soc. One of the Cytherellidæ, belonging to the Platycopa group, and an Ostracod were included in the Second Number of that Part in 1884, p. 72. In the "Journ. Roy. Geol. Soc. Ireland," N.S., vol. v., pt. 3, 1880, pp. 90 and 94, Mr. W. H. Baily enumerated a few Irish Carboniferous species that had been named by Kirkby and Jones. In the "Quart. Journ. Geol. Soc.," vol. xlii., 1886, pp. 508–513, ten species are tabulated by Jones and Kirkby, none of them new.

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* See the "Ann. and Mag. Nat. Hist.," ser. 3, vol. xviii., pp. 37–51.

Having in the interval from 1866 received, through the kindness of Mr. Joseph Wright, F.G.S., of Belfast, the late W. H. Baily, F.G.S., and other friends, numerous specimens of Ostracoda (Podocopa) from the Carboniferous formations of Ireland, Messrs. Kirkby and Jones have been desirous of putting them, together with those already indicated, in a convenient arrangement, so that geologists and naturalists in general should be able to form their judgment on this branch of Palæontology in Ireland. It is only recently, however, that this material has been sufficiently examined for all the species to be determined. As some of them appear to be new, and several others are as yet unrecorded from Ireland, the following notes and lists of species may be of use to palæontologists.

Many of the specimens have been treated more or less fully in some of the Memoirs scattered in various publications, such as the Ann. Mag. Nat. Hist., Quart. Journ. Geol. Soc., Geol. Mag., Proc. Geol. Assoc., &c. Several however, have not hitherto been adequately illustrated, and some are new. Of the species and notable varieties there are—belonging to Leperditia, 10; Beyrichia, 3; Beyrichiopsis, 2; Kirkbya, 4; Ulrichia, 1; Synaphe, gen. nov., 2; Bythocypris, 2; Macrocypris, 1; Argillœcia, 1; Krithe, 2; Bairdia, 7; Cytherella, 7—altogether 42. The specimens treated of have come from Donegal, Londonderry, Tyrone, Down, Sligo, Longford, Mayo, and Cork.

It is proposed to give a concise descriptive and bibliographical account of each form, with its range and localities, accompanied by good illustrations where necessary.

Most of the specimens are from two localities; namely, Cultra, near Holywood, Belfast Lough; and Carland, near Dungannon. In both cases they are in the Lower Limestone-Shale. There are also some examples from the "red Carboniferous Limestone," of Castle Espie, near Belfast, and from other local Carboniferous strata.

Both the Cultra and the Carland shales appear to be rich in Ostracoda, so far as may be judged from the small quantities in hand. In all probability both localities would well repay further search for these and other microzoa. This belief would probably be true of Ireland as a whole; for, though this paper more than doubles the number of the smaller Ostracoda previously known as occurring in that country, the list is still only a short one when the great area and thickness of the rocks are considered.

The species from Cultra and Carland form a group that is essentially Lower Carboniferous. All of them, putting aside the seven new forms, and excepting *Bythocypris Phillipsiana*, var. *carbonica*, are found in the Calciferous Sandstone series of Scotland, or in beds of equivalent position in the North of England. And, leaving out *Leperditia Okeni* and *L. acuta*, they are confined to Lower Carboniferous strata, or to such beds and the lower portion of the Carboniferous

Limestone series in Scotland, and to the Yoredale Rocks in England, succeeding immediately above.

The few species from Castle Espie indicate a higher horizon. All of them are common fossils right through the Yoredale Rocks and Carboniferous Limestone series.

Description of Species.

1. **Cytherella valida**, Jones & Kirkby.

1884. *Cytherella valida*, Jones & Kirkby, "Monogr. Carbonif. Entom.," Pal. Soc., p. 70, pl. vi., figs. 2 *a–c*; pl. vii., figs. 13 *a*, *b*, *c* (?).
1885. ,, ,, Jones & Kirkby, Geol. Mag., dec. 3, vol. ii., p. 540.
1886. ,, ,, Jones & Kirkby, Quart. Journ. Geol. Soc., vol. xlii., p. 509.

There are several good carapaces from Carland, and other specimens from Cultra, of this fine *Cytherella;* though scarcely so large and robust as it occurs in the North of England,* where it is often very abundant in Lower Carboniferous strata.

The figures and description in the Palæontographical Society's volume of Monographs for 1884 fail to give a good idea of this species. In Pl. vi., figs. 2 *a* and 2 *b* have the posterior end placed upwards instead of downwards, which is described at p. 70 as being semicircular and narrow, whereas it is obliquely asymmetrical and broader (higher) than the front part of the valve.

The obliquity at the hinder margin varies in individuals, sometimes only slightly interfering with the posterior curve, and then closely resembling *Cytherella extuberata.* In other cases the postero-ventral obliquity modifies this hinder margin so much that it is bluntly acute above the medial line, somewhat like the appearance in *C. attenuata*, where its postero-ventral portion is obliquely truncate.

2. **Cytherella extuberata**, Jones & Kirkby.

1880. *Leperditia extuberata*, Jones & Kirkby, MS. Quart. Journ. Geol. Soc., vol. xxxvi., pp. 573, 576, 588.
1886. *Cytherella extuberata*, Jones & Kirkby, Geol. Mag., dec. 3, vol. viii., p. 251, pl. vii., figs. 13 *a–d*; Quart. Journ. Geol. Soc., vol. xlii., p. 510.

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* It is good and common in Northumberland and Westmoreland, as well as at Calees, East Cumberland.

Well preserved carapaces are common in the Cultra Shale. Some are more symmetrically rounded behind than others.

This is a very abundant and wide-spread species in Lower Carboniferous strata in the east of Scotland (Roxburghshire and Fifeshire); and in some localities in Northumberland. Also in the deep-lying Carboniferous Shale of Northamptonshire, as proved by the Gayton Boring.

3. **Cytherella attenuata**, Jones & Kirkby.

1880. *Leperditia attenuata*, JONES & KIRKBY, MS. Quart. Journ. Geol. Soc., vol. xxxvi., pp. 568, 573, 588.
1886. *Cytherella attenuata*, JONES & KIRKBY, Geol. Mag., dec. 3, vol. iii., p. 252, pl. vii., figs. 14 *a*, *b*, *c*; Quart. Journ. Geol. Soc., vol. xlii., p. 510.

Rare and badly-preserved single valves are present in the Carland shale.

This species occurs in the Calciferous Sandstone of Fifeshire, and the Lower Carboniferous Shale of Gayton, Northamptonshire.*

4. **Cytherella incurvescens**, sp. nov.

(Plate XI., figs. 1–5.)

In the Cultra Shale *Cytherellæ* are relatively numerous, but not readily grouped as species. One series is new, and may be described as sub-oblong in shape, rounded almost equally at the ends, the anterior being usually the highest. The valves are more or less constricted; the ventral margin always, and the dorsal in some cases, being incurved. The overlap of the left valve by the right is moderate. Edge view nearly lenticular in some cases, lanceolate in others; surface smooth.

Taking the chief series of these Cultra specimens as very closely allied and

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* This and the preceding species (*C. extuberata*) are present in great numbers in the lower beds of the Calciferous Sandstone series of Fife. Some of the cement-stones, and shales immediately overlying them, are full of their carapace-valves; now and then associated with other Ostracoda—species of *Kirkbya* and *Beyrichiopsis*—at other times apparently alone. For a few hundred feet of these beds these two *Cytherellæ* (*extuberata* and *attenuata*) are decidedly the prevailing and most characteristic Ostracoda. Afterwards their place is taken by that other very common Lower Carboniferous form, *Leperditia Scotoburdigalensis*.

When occurring as separate valves, more or less flattened by pressure (as they often are), they very much simulate *Leperditiæ* in outline, and are easily mistaken for members of that genus. They were thus at first mistaken by us. Well-preserved carapaces, or good single valves showing the interior, however, undoubtedly prove them to belong to *Cytherella*.

probably interchangeable forms, agreeing in their oblong and round-ended shape and incurved ventral line, we might still separate them into three groups or varieties. Var. 1. Incurved or hollow on both the dorsal and the ventral margin; ends rounded equally or nearly so (fig. 1). Var. 2. Slightly incurved on the back; sloping on the postero-dorsal margin; ventral incurved (fig. 4). Var. 3. Straight dorsal border; ventral incurved; ends rounded, having very slight but recognizable variations from the semicircular in different individuals (figs. 2, 3, and 5). All these have the valves most convex medially, and their edge views are lenticular or lanceolate.

We give the new specific name on account of the gradational aspect of the varying amount of constriction.

There are several published *Cytherellæ* sub-oblong in shape, and more or less constricted, and in so far like the above; but none of them agree with the latter in profile (edge view), and slight differences can be recognized as to other features.

Oblong and more or less constricted, smooth *Cytherellæ** :—

C. parallela, Reuss, Cretaceous; Brady, Recent.
C. Fischeri, Terquem, Tertiary.
C. pulchra, Brady, Recent.
C. Scotica, Brady, Recent.
C. Murchisoniana, Jones & Kirkby, Carboniferous.

Cytherella Smithii, a Silurian species (Ann. Mag. Nat. Hist., ser. 5, vol. xix., 1887, p. 192, pl. vii., figs. 15, 16), one of the more or less constricted forms, varies in outline even more than the species under notice. It differs from the latter, more especially in its edge-view.

There are still other *Cytherellæ* in the Cultra Shale, such as fig. 6, which we hesitate to name. Some, though much shorter than *C. attenuata*, approach it, one end being obliquely truncate, and the other obliquely rounded.

5. **Cytherella simplex** (?), Jones, Kirkby, and Brady.

1884.	*Cytherella simplex*, . .	JONES, KIRKBY, & BRADY, "Monogr. Brit. Carb. Entom.," Pal. Soc., p. 75, pl. vii., fig. 3*a*, *b*.
1886.	,, ,,	JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xlii., p. 509.

Of the many published figures of oval and suboval *Cytherellæ*, from the Carboniferous and other formations, none of them corresponds with this specimen

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* See "Monograph Brit. Foss. Biv. Entom. Carbonif.," Pal. Soc. 1884, pp. 57–69.

from Carland so closely as fig. 3*a* (1884) above referred to, which came from the Lower Limestone series, Raes Gill, Lanarkshire. The evidence at hand, however, is insufficient for us to determine their actual identity.

6. **Cytherella recta**, Jones, Kirkby, and Brady.

1884. *Cytherella recta*, . . JONES, KIRKBY, & BRADY, "Monogr. Brit. Carbonif. Entom.," pp. 68–71, pl. vi., figs. 6*a*, *b*; 11*a*, *b*.
1885. ,, ,, . . JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 510; 1887, Proceed. Geol. Assoc., vol. ix., p. 502.

Valves sub-oblong; ends rounded, generally somewhat unequal; dorsal and ventral borders straight and parallel; surface smooth; edge-view cuneiform.

In the Carboniferous Limestone at Castle Espie, County Down; and in Lanarkshire, Scotland.

7. **Cytherella Hibernica**, Jones, Kirkby, and Brady.

(Plate XI., figs. 7*a*, *b*.)

1884. *Cytherella Hibernica*, . . JONES, KIRKBY, & BRADY, "Monogr. Brit. Biv. Entom. Carb.," Part I., Pal. Soc., p. 72, pl. vi., figs. 13*a*, *b*.
1886. ,, ,, . . JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xlii., p. 510.

Broadly sub-ovate; ends rounded unequally; much compressed.

Found in the yellow shale of the Carboniferous series at Cultra, on Belfast Lough, not far from Holywood. The locality and its strata and fossils are referred to in the "Mem. Geol. Surv. Ireland, Explan. Sheets, 37, 38, and 29," 1871, pp. 10, 16, 17. Also in the "Ninth Annual Report Belfast Nat. Field-Club," 1872, pp. 33–37.

8. **Leperditia Okeni** (Münster).

(Plate XI., figs. 8*a*, *b*, 9, 10.)

1830. *Cythere Okeni*, . . . MÜNSTER, Jahrbuch für Mineral. u. s. w. Jahrg. 1830, p. 65, No. 15.
1865. *Leperditia Okeni*, . . JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xv., p. 406, pl. xx., figs. 1–3.

1867.	*Leperditia Okeni* (and varieties),	JONES & KIRKBY, Trans. Geol. Soc. Glasgow, vol. ii., p. 219.
1875.	*Leperditia Okeni*, .	JONES & KIRKBY, Ann. Mag. Nat Hist., ser. iv., vol. xv., p. 54, pl. vi., fig. 1.
1880.	,, ,,	KIRKBY, Quart. Journ. Geol. Soc., vol. xxxvi., pp. 561, 564, 567, 573, 575, 576, 578, 588.
1884.	,, ,,	JONES & KIRKBY, Geol. Mag., dec. 3, vol. i., p. 356, pl. xii., fig. 3.
1884.	,, ,,	VINE, Proc. Yorksh. Geol. Polyt. Soc., vol. viii., p. 235, pl. xii., figs. 10, 10*a*.
1884.	,, ,,	VINE, The Naturalist, No. 113, p. 144.
1885.	,, ,,	JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 510; 1887, Proc. Geol. Assoc., vol. ix., p. 504.

The carapaces of this important species are somewhat variable in their contour, and other features, and vary in size from 1 mm. to 3·5 mm. in length. Truly Leperditioid in shape, they are sub-ovate, with a straight hinge-line of about half the length of the valve. The posterior extremity is nearly semicircular, and the anterior is obliquely curved; the ventral margin has a uniform gentle curve in the left (smaller) valve, but it is oblique or elliptical in the right (larger) valve. Hence the right valve is higher behind than the other valve, and more obliquely ovate; while the postero-dorsal slope is present in each valve.

The edge of the right valve slightly predominates along the hinge-line, and overlaps the other valve ventrally, more so in large specimens.

The surface of the valves is convex or gibbose, smooth, and sometimes showing an ocular tubercle, but the muscle-spot is frequently obsolete.

Fairly good examples of *L. Okeni*, of moderate size, are present in the shales of the Lower Carboniferous series at Carland, but none nearly so large as those we have had from Holwell and Weston-super-Mare in Somerset, collected by the late Mr. Charles Moore, F.G.S., and as yet unpublished.

Fig. 8 is a rather large specimen of *L. Okeni* from Fermanagh, among General Portlock's specimens of *Cypris subrecta*, &c., in the Museum of Practical Geology, London.

L. Okeni has been found in the Carboniferous strata of Germany (Bavaria), Russia, Nova Scotia, in the Lower and Upper Carboniferous formations of the British Isles, and in the Devonian of Belgium (Givet Limestone).

Several small forms allied to this species, if not varietal modifications, and indeed possibly dwarfed individuals in some instances, occur in our Carboniferous Shales; and although intermediate gradations often appear, they are of such uncertain value that we have found it best to treat the most striking of these forms as "species," rather than as varieties, in which category we have placed them, now and again, in former notices and memoirs.

9. **Leperditia suborbiculata** (Münster).

(Plate XI., fig. 11.)

1830.	*Cythere suborbiculata*, .	MÜNSTER, Jarhb. f. Min. u. s. w., p. 65, No. 16.
1865.	*Leperditia suborbiculata*,	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xv., p. 407, pl. xx., figs. 7*a–c*.
1885.	,, ,,	JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 510; 1887, Proceed. Geol. Assoc., vol. ix., p. 504.

This relatively rare species is one of the degenerate *Leperditiæ*, in which the chief superficial characteristics are obsolete.

It has been found in the Mountain-Limestone of Bavaria, and of both the South and the North of England, and in the Lower Carboniferous series of both East and West Scotland. In Ireland it occurs in the Carland Shales.

10. **Leperditia Scotoburdigalensis** (Hibbert).

(Plate XI., fig. 12.)

1836.	*Cypris Scotoburdigalensis*,	HIBBERT, Trans. Roy. Soc. Edinb., vol. xiii., p. 179; Portlock, 1843, Report Geol. Londonderry, p. 316.
1844.	*Cythere arcuata* (?), *scutulum*, &c.,	M'COY, "Synops. Char. Carb. Foss. Ireland," pp. 165, &c., pl. xxiii., fig. 9, &c.
1861.	*Cypris Scotoburdigalensis*,	SALTER, Mem. Geol. Surv., Expl. Sheet 32, p. 145.
1862.	*Cythere* vel *Cytheropsis Scotoburdigalensis*,	JONES, "Monogr. Foss. Esth.," Pal. Soc., p. 119.
1863.	*Leperditia Scotoburdigalensis*,	JONES & KIRKBY, Rep. Brit. Assoc. for 1863, Trans. Sections, p. 80; 1863, Geologist, vol. vi., p. 460; and *L. Okeni*, var. *Scotoburdigalensis*, 1866, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., pp. 35, 44, 45, &c.
1865.	*Leperditia Okeni*, "small variety,"	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xv., p. 406.

1867.	*Leperditia Okeni*, var. *Scotoburdigalensis*, .	JONES & KIRKBY, Trans. Geol. Soc. Glasgow, vol. ii., pp. 216, 219.
1872.	,, ,, .	J. WRIGHT, Ninth Ann. Rep. Belfast Nat. F. Club, p. 35.
1880.	,, ,, .	KIRKBY, Quart. Journ. Geol. Soc., vol. xxxvi., p. 580.
1884.	,, ,, .	JONES & KIRKBY, Geol. Mag., dec. 3, vol. i., p. 357, pl. xii., figs. 1, 2.
1884.	*Leperditia Scotoburdigalensis*,	JONES, Proceed. Berwickshire Nat. Club, vol. x., No. II., pp. 314, 321, pl. ii., figs. 7 and 9.
1886.	,, ,, .	JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xlii., pp. 500, 503, and Table, p. 506.
1886.	,, ,, .	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 5, vol. xviii., p. 254, pl. vii., figs. 4*a*, *b*; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 510; 1887, Proceed. Geol. Assoc., vol. ix., p. 504.

Short-broad-oblong, straight above, more or less convex below; the ends fully rounded, rather unequal, one (posterior) having a slight postero-dorsal slope, giving some obliquity to that end; the anterior has a dorsal angle.

Ocular spot and muscle-mark, one or both, sometimes apparent; hinge-line more or less than two-thirds of the length of the valve.

L. Scotoburdigalensis, like some varieties of *L. Okeni* and allied species, has lost more or less completely some or all of the real Leperditian characteristics—ocular spot and its escutcheon, muscle-mark and its radiate lines, traces of nuchal sulcus, and, to a great degree, the overlapping ventral edge of the larger valve. These featureless valves of degenerate species retain only the Leperditian outline, and even that is modified often by the want of strong dorsal angles; and they have thus come (by retrogression) to represent their probable progenitor, the far-away and early *Aparchites* of the Silurian seas.

Examples of this well known Burdiehouse fossil are found among the other species from Cultra, but only rarely. It occurs also at Dromard.

In Fife and other parts of Scotland (as well as at Burdiehouse) it occurs in swarms in some of the shales and limestones of the Lower Carboniferous series.

This is a common form in some of the Lower Carboniferous strata in Scotland* and the North of England, as well as in Ireland.

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* The range of Carboniferous Ostracoda in Western Scotland is carefully tabulated by Dr. John Young, in the "Transact. Geol. Soc. Glasgow," vol. ix., part 2, 1893, pp. 310–312.

11. **Leperditia subrecta** (Portlock).

(Plate xi., figs. 13, 14.)

1843.	*Cypris subrectus* [*ta*], . .	PORTLOCK, "Rep. Geol. Londonderry," p. 316, pl. xxiv., fig. 13*b*.
1860.	*Cythere subrecta*, . . .	GRIFFITH, Journ. Geol. Soc. Dublin, vol. ix., p. 48.
1866.	*Leperditia Okeni*, var. *subrecta*,	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., pp. 39, 42–47; *L. subrecta*, pp. 48–51.
1864.	,, *subrecta*, . .	JONES & KIRKBY, Rep. Brit. Assoc. for 1863, Trans. sections, p. 80.
1884.	,, ,, . .	JONES, Proc. Berwicksh. Nat. Club, vol. x., p. 321, pl. ii., fig. 8.
1886.	,, ,, . .	JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xlii., p. 510.
1887.	,, ,, . .	JONES & KIRKBY, Proc. Geol. Assoc., vol. ix., p. 504.

Sub-oblong, with rounded, not quite equal extremities, ventral margin gently convex, and hinge-line straight, as much as three-fourths of the length of the valve. In some larger specimens, the hinge-line is nearly five-sixths of the length of the valve, and thus the dorsal angles extend further to meet the terminal curves without any antero- and postero-dorsal slopes. Ocular tubercle sometimes present. Between these extreme modified Leperditian outlines and the typical *L. Okeni* there are "intermediate gradations among the countless individuals that swarmed in the muddy lagoons everywhere in the Carboniferous period," *op. cit.*, 1884, p. 322.

Characteristic specimens of this fine species occur in the Cultra Shale; the valves always detached and somewhat flattened. Sir Richard Griffith, in 1860, gave as a locality—"Yellow Sandstone; Largamore, Bangor, Co. Mayo." General Portlock referred to the Carboniferous shales of Tyrone, Derry, and Fermanagh. It is indeed more persistent than any other Ostracod in the Carboniferous strata of Ireland.

It is known also from the Lower Mountain-limestone of Northumberland, occurring in a dark shale at Tweedmouth, with *L. Scotoburdigalensis*.

L. subrecta is easily distinguished from that much more common and typical member of the genus, *Leperditia Okeni*, by its usually larger size, greater relative length of carapace, and the less obliquity of its valves. Both species are found in

Lower Carboniferous strata, but *subrecta* is more often present at low horizons than *Okeni.* In the East of Scotland *L. subrecta* occurs in the Cornstone group of the Calciferous Sandstone series; and in the overlying Cement-stone group of the same region it is found only in the lower beds. *L. Okeni*, on the other hand, ranges from the Cornstone group into the Upper Limestones and Marine Shales of the Carboniferous Limestone series of Scotland; and well towards the top beds of the Yoredale rocks of the North of England.

12. **Leperditia inornata** (M'Coy).

(Plate XI., figs. 15 *a*, *b*, 16 *a*, *b*; Plate XII., figs. 1, 2 *a*, *b*, *c*, 3 *a*, *b*.)

1843. *Cythere inornata*, . .	M'COY, "Synops. Char. Carb. Foss. Ireland," p. 167, Pl. xxiii., fig. 18.
1866. *Leperditia Okeni*, var. *inornata*,	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., p. 44; 1875, A. M. N. H., ser. 4, vol. xv., p. 54, pl. vi., fig. 2; 1892, A. M. N. H., ser. 6, vol. vi., p. 303, pl. xvi., fig. 2.

These small Leperditioid valves are obliquely sub-ovate, the longest diameter being from the antero-dorsal to the postero-ventral region at a low angle. The anterior is smaller than the posterior moiety. The valves have a relatively longer hinge-line than that shown by the "short form" of *L. Okeni*, fig. 2, pl. xx., 1865, Ann. Mag. Nat. Hist.; and they vary towards *L. acuta* and other allies.

Prof. M'Coy's described specimens came from the Cultra Shales, in company with *Leperditia subrecta* and *L. Scotoburdigalensis*, and in some instances showed the eye-spots. These specimens, in Sir Richard Griffith's collection, were in a bluish-grey fissile shale, fine-grained and micaceous.

Besides the Irish specimens from Cultra, and near Bundoran, Co. Donegal, some of which latter are here figured, we have had similar forms from Russia and Mongolia.

In our previous notices of the small Carboniferous *Leperditiæ*, we have been influenced by the more or less tangible features and alliances of the several not very dissimilar forms; and have regarded them sometimes as varietal, sometimes as so-called "specific," modifications of *L. Okeni*, as the synonymies here show. We think now, however, that it is advisable, as well as convenient, to arrange them as "species," as in the present instance.

13. **Leperditia Wrightiana**, sp. nov.

(Plate XII., figs. 4, 5.)

Besides the foregoing species of *Leperditia*, there are two valves (from Carland) of another form, evidently belonging to this genus, but unknown to us, and apparently undescribed. These belong to the group of nearly featureless *Leperditiæ*, in which the usual characteristics are obsolete.

The larger specimen, nearly oblong, is one-sixteenth inch in length; rather less than twice as long as high; higher and altogether larger behind than before; and with a slightly oblique swing backward. The dorsal border is long and straight; the ventral border is boldly rounded, with a slight obliquity; and the anterior extremity is smaller than the posterior. The valves are convex, and appear to have been comparatively thin; a stout rim bounds their free margins; and the surface, so far as can be judged, is smooth.

Had these specimens been less in height, and thus relatively longer, they would have agreed with the characters of *L. parallela**, Jones & Kirkby. In their general outline, they come somewhere between that species and the elongate forms allied to *L. Okeni*, such as *L. oblonga*, Jones & Kirkby, Ann. Mag. Nat. Hist. ser. 3, vol. xv., 1865, p. 407, pl. xx., fig. 5. For the specimens under notice, we propose the name *L. Wrightiana*, in compliment to Mr. Joseph Wright, F.G.S., who supplied us with the Carboniferous Shale from Carland, near Dungannon.

We have a *Leperditia* of somewhat similar outline, though of less size, from the Carboniferous Limestone of Clitheroe, Lancashire; but it has the surface covered with large and deep pits. Another possibly kindred form occurs in the Glencartholm beds of Eskdale, Dumfriesshire, which has also a pitted surface, somewhat like the last-mentioned.

Now and then, among the countless multitudes of *L. Scotoburdigalensis*, as they occur in the Calciferous Sandstone of Fife, we have noticed a larger and longer form of carapace that does not fit in with any species already described, and which may be of near kinship to this form from Carland.

14. **Leperditia acuta**, Jones & Kirkby.

1865. *Leperditia Okeni*, var. *acuta*, JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xv., p. 406, pl. xx., figs. 4 *a*, *b*.

1884. ,, ,, JONES & KIRKBY, Geol. Mag., dec. 3, vol. i., p. 357, pl. xii., figs. 4 *a*, *b*.

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* Ann. Mag. Nat. Hist., ser. 3, vol. xv., 1865, p. 407, pl. xx., figs. 6 *a*, *b*.

1885. *Leperditia Okeni*, var. *acuta*, JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540.

1886. ,, ,, ,, JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xlii., p. 510; Ann. Mag. Nat. Hist., ser. 5, vol. xviii., p. 256, pl. vii., fig. 9.

There are two or three carapaces of this *Leperditia* from Carland. They agree well with the figure given of the species in the "Annals of Natural History" in 1886, and can be distinguished from *L. Okeni* by the smaller and sharper anterior extremity.

L. acuta is of rare occurrence, but is known from the Lower Carboniferous strata of Scotland, Westmoreland, Northumberland, Somerset, and Bavaria; and from the Coal-measures of Nova Scotia.

15. **Leperditia rhombica**, sp. nov.

(Plate XII., fig. 6.)

Together with *L. Okeni*, in the Carland Shales, occur some larger forms, having the ventral margin more strongly arched, and the posterior extremity subangulate. In the latter respect, it is suggestive of *L. Youngiana*,* Jones & Kirkby, but differs from that species in the dorsal angles, and in the non-punctate surface and more swollen curvatures of the valves. It is an ally of *L. Okeni*; and, as in the case of so many other congeneric forms, it is more convenient to regard it as a "species" than to catalogue it as one of the varietal modifications.

16. **Leperditia compressa**, Jones & Kirkby.

1867. *Leperditia compressa*, . JONES & KIRKBY, Trans. Geol. Soc. Glasgow, vol. ii., p. 219; 1886, Ann. Mag. Nat. Hist., ser. 5, vol. xviii., p. 256, pl. vii., figs. 7 *a*, *b*; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 511; 1887, Proc. Geol. Assoc., vol. ix., p. 504.

Sub-oval; hinge-line distinct, without angles; surface smooth, and very much flattened; variable in some of its features.

In Lower Carboniferous rocks in Stirlingshire and Durham, and in the Carboniferous Limestone near Bundoran, Co. Donegal.

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* Ann. Mag. Nat. Hist., ser. 5, vol. xviii., 1886, p. 254, pl. vii., figs. 3 *a*, *b*, *c*.

17. **Leperditia ? amygdalina** (M'Coy),

"Synops. Carb. Foss. Ireland," p. 165, pl. xxiii., fig. 8, has not been determined by us; but a possible *Leperditia* (?) like it was observed in another of Sir Richard Griffith's specimens (from Cultra), see p. 43, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., 1866.

"*Leperditia amygdalina*" is comprised in Jones & Kirkby's "Table of the Distribution of British Carboniferous Ostracoda," Quart. Journ. Geol. Soc., vol. xlii., 1886, p. 510.

18. **Beyrichia craterigera**, Brady.

1885. *Beyrichia craterigera*, BRADY (Jones & Kirkby), Geol. Mag., dec. 3, vol. ii., p. 540; 1886, vol. iii., p. 439, pl. xii., figs. 7 *a*, *b*; Quart. Journ. Geol. Soc., vol. xlii., p. 511.

Three or four fairly well preserved individuals are present among the Carland Ostracoda, showing the strong overlap of the right valve, the reticulated surface, and other features characteristic of this species.

It is found also in the Lower Carboniferous rocks of Northumberland, Westmoreland, and Lancashire.

19. **Beyrichia Hibernica**, sp. nov.

(Plate XII., figs. 7 *a*, 7 *b*.)

Perhaps the most interesting specimens from Cultra are two separate valves of a *Beyrichia* which comes nearer to *Beyrichia Nova-scotica*, Geol. Mag., dec. 3, vol. i., 1884, p. 358, pl. xii., figs. 5, 6 (Jones & Kirkby), than to any other Carboniferous species. Although both the specimens are attached to the matrix, the margins appear to be clearly shown.

The larger specimen (fig. 7*a*) is nearly $\frac{1}{13}$ inch in length, and subovate in general outline; the upper edge is straight, and the ventral and extreme margins regularly convex.

The area of this valve is modified by being raised into four or five lobes and bosses, with corresponding furrows or depressions between them, somewhat as follows:—Taking the posterior extremity to be indicated by the usual "gigot" lobe, which is large, sub-triangular, and sub-marginal, there is in front of it, close to the ventral margin, a smaller lobe or elongated boss; and this is connected with a broader lobe that curves up, and terminates in a round boss close to the dorsal border; behind the latter boss, and nearer the "gigot" lobe, is a sub-central ovate boss; within the antero-dorsal angle is a small elongate lobule, rising from a narrow ridge that curves downward, and runs out near the ventral border.

The other and smaller example (fig. 7 *b*) shows some differences: it is more oblong in outline, the extremities being nearly of equal height, and the ventral margin is less convex; the tubercles or bosses are more isolated, and the antero-dorsal swelling is produced forward and teat-like.

Though resembling *Beyrichia Nova-scotica* in some particulars, these specimens show such differences as to render it probably wiser to look upon them as belonging to a new form than to identify them with a species as yet known to occur only on the other side of the Atlantic. It is therefore kept distinct and named *B. Hibernica.*

We may compare this interesting form with Ulrich's *Beyrichia simulatrix* and Eichwald's* *B. colliculus*† and *B. gibberosa*‡ (all Carboniferous species); and possibly they may all be regarded as indicative of a passage from *Beyrichia* to *Drepanella.*

20. **Beyrichia gigantea**, Jones & Kirkby.

An extraordinarily large Beyrichian form (*Beyrichia gigantea*), from Cork, is noted and figured in the "Monogr. Brit. Carbonif. Entom.," Pal. Soc., 1884, p. 88, pl. iv., fig. 28. It is known also from Derbyshire.

21. **Kirkbya Permiana**, Jones.

1850.	*Dithyrocaris Permiana*,	Jones, in King's "Monogr. Permian Foss.," Pal. Soc., p. 66, pl. xviii., figs. 1*a*–*d*.
1854.	*Ceratiocaris Permiana*,	Jones, in Morris's "Catal. Brit. Foss.," edit. 2, p. 103.
1858.	*Leperditia* (?) *Permiana*,	Kirkby, Ann. Mag. Nat. Hist., ser. 3, vol. ii., p. 434, pl. xi., figs. 5–13.
1859.	*Kirkbya Permiana*, .	Jones & Kirkby, Transact. Tyneside Field-Club, vol. iv., p. 129, pl. viii., figs. 1, 2, 3, and 5; pl. x., figs. 5, 7, 9–12.
1861.	,, ,, .	Kirkby, Quart. Journ. Geol. Soc., vol. xvii., p. 308.
1861.	,, ,, .	Jones & Kirkby, Trans. Geol. Soc., Glasgow, vol. ii., p. 220.
1867.	,, ,, .	Richter, Zeitsch. Deutsch. Geol. Ges., Jahrg. 1867, p. 224, pl. v., figs. 1–3.

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* Journ. Cincinn. Nat. Hist. Soc., vol. xiii., p. 205, pl. xviii., figs. 7*a*, *b*.

† "Lethæa Rossica," livr. 7, 1860, p. 1348, pl. lii., figs. 1 *a*, *b*.

‡ *Ibid.*, p. 1349, pl. lii., figs. 11 *a*, *b*, *c*.

1882. *Kirkbya Permiana*, . KIRKBY, Quart. Journ. Geol. Soc., vol. xxxvi., p. 588.
1885. ,, ,, . JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540; Ann. Mag. Nat. Hist. ser. 5., vol. xv., p. 177, pl. iii., fig. 1 ; 1886, Quart. Journ. Geol. Soc., vol. xlii., p 511; 1887, Proceed. Geol. Assoc., vol. ix., p. 508.

Sub-oblong, straight above, curved below; ends bending upwards to make the terminal dorsal angles; surface depressed, more or less distinctly reticulate, and marked with a subcentral pit.

In Ireland it has been met with at Cultra. In the shales of the Carboniferous Limestone series it is found at many places* in Scotland and the North of England. In the Permian rocks it occurs in Durham and Yorkshire; and at Saalfeld, Gera, and elsewhere in Germany.

22. **Kirkbya spiralis**, Jones & Kirkby.

1880. *Kirkbya spiralis*, . . JONES & KIRKBY, MS. Quart. Journ. Geol. Soc., vol. xxxvi., pp. 564, 568, 573, 588.
1884. ,, ,, . . JONES & KIRKBY, Proceed. Berwicksh. Nat. Club, vol. x., p. 323, pl. ii., figs. 12, 13.
1885. ,, ,, . . JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 5, vol. xv., p. 184, pl. iii., figs. 9, 10; Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 511.

Represented by several individuals from Cultra, most of which are in good condition, showing the peculiar concentric or spiral riblets that ornament the valves, as well as the central pit or umbilicus.

This Lower Carboniferous species is known in Northumberland, Cumberland, Fifeshire, and Linlithgowshire.

23. **Kirkbya plicata**, Jones & Kirkby.

1880. *Kirkbya plicata*, . . JONES & KIRKBY, MS. Quart. Journ. Geol. Soc., vol. xxxvi., pp. 576, 578, 588.
1885. ,, ,, . . JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 5, vol. xv., p. 184, pl. iii., figs. 9, 10 *a*, *b*.
1886. ,, ,, . . JONES & KIRKBY, Geol. Mag., dec. 3, vol. iii. p. 250, pl. vii., figs. 1 *a*, *b*, 2, 3 *a*, *b*.

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* For a long list of localities, see Ann. Mag. Nat. Hist., ser. 5, vol. xv., p. 179, 1885.

Some single valves with longitudinal ribs, and a reticulated surface, from Carland, come nearer to this species than to any other, and are referred to it without much doubt.

This type of *Kirkbya*, however, comes near to *Beyrichiopsis*, and the discovery of specimens of it with marginal fringes would cause their removal to that genus.

This is not a common species; known in England only in Somerset; in Scotland, however, it has been found in Fifeshire, Edinburghshire, Roxburghshire, Argyleshire, and Peeblesshire.

24. **Kirkbya costata** (M'Coy).

1844.	*Cythere costata*, . .	M'COY, "Syn. Char. Carb. Foss.," p. 165, pl. xxiii., fig. 11.
1866.	*Kirkbya costata*, . .	JONES & KIRKBY, Ann. & Mag. Nat. Hist., ser. 3, vol. xviii., p. 43.
1884.	,, ,, . .	JONES, KIRKBY, & BRADY, "Monogr. Brit. Foss. Bivalve Entom.," Pal. Soc., p. 89, pl. vii., fig. 17.
1885.	,, ,, . .	JONES, & KIRKBY, Ann. & Mag. Nat. Hist., ser. 5, vol. xv., p. 186, pl. iii., figs. 13 *a*, *b*, 14 *a*, *b*; Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 511.
1891.	*Kirkbya* (? *Barychilina*) *costata*,	ULRICH, Journ. Cincinnati Soc. Nat. Hist., vol. xiii., p. 208, pl. xviii., figs. 2 *a*, *b*.

This species is present at both Cultra and Carland. It is a strongly-marked species, and not easily mistaken, even when in poor or fragmentary condition. Professor M'Coy described it as of rare and solitary occurrence. It certainly is not among the most common of Carboniferous Ostracoda, though in some Northumberland localities it is very abundant; notably so at Plashetts in Lower Carboniferous strata.

It has been found also in the Carboniferous Limestone series in Shropshire, Somerset, Westmoreland, Cumberland, Northumberland, Lanarkshire, and Fifeshire.

25. **Beyrichiopsis fimbriata**, Jones & Kirkby.

1886.	*Beyrichiopsis fimbriata*,	JONES & KIRKBY, Geol. Mag., dec. 3, vol. iii., p. 434, pl. xi., figs. 3–10, and pl. xii., fig. 5 (?); Quart. Journ. Geol. Soc., vol. xlii., p. 511.

Examples of one or more species of *Beyrichiopsis* are comparatively common among the Ostracoda from Carland. Some of them show portions of the marginal fringe, and of the upper rib or dorsal crest. One fragmentary specimen from Carland bears the remnants of two lobes and a dorsal crest. Probably, when complete, the valve may have been very much like that of *Beyrichiopsis fimbriata,* fig. 10, pl. xi., Geol. Mag., 1886. The fringe and ridges may be damaged, undeveloped, or obsolete. There are some fringeless forms, probably belonging to this group, in the Cultra Shales; and a fringed specimen, without ridges (from Cultra) is figured in the Geol. Mag., 1885, pl. xii., fig. 5.

Beyrichiopsis fimbriata belongs to the Lower Carboniferous series of Northumberland, Roxburghshire, Linlithgowshire, and Fifeshire.

26. **Beyrichiopsis fortis**, Jones & Kirkby.

1886. *Beyrichiopsis fortis,* . JONES & KIRKBY, Geol. Mag., dec. 3, vol. iii., p. 435, pl. xii., figs. 1–3; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 511.

Judging from their size, it is not unlikely that the larger specimens from Carland belong to *Beyrichiopsis fortis*, although they have not preserved the longitudinal riblets.

B. fortis is found in the Calciferous Sandstone of Roxburghshire.

27. **Synaphe annectens**, Jones & Kirkby (gen. nov.).

(Plate XII., figs. 8–10, 12, 13, 15, 16; and variety figs. 11 and 14).

1866. *Kirkbya annectens,* . JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., pp. 42 and 44; 1867, Trans. Geol. Soc. Glasgow, vol. ii., p. 220.

1872. ,, ,, . J. WRIGHT, Ninth Annual Report Belfast Nat. Field-Club, p. 35.

1885. ,, ,, . JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 5, vol. xv., p. 182, pl. iii., figs. 7 *a–d*; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 511; 1887, Proc. Geol. Assoc., vol. ix., p. 508.

Sub-oblong, with rounded, almost equal ends; straight hinge-line, and gently convex or slightly sinuous ventral border; surface marked with a medio-dorsal sulcus, of variable proportions, narrow or broad, between two tubercles or lobules, also of variable dimensions. A more or less distinct, narrow ridge, straight or slightly curved, passes along the ventral region below the two bosses, scarcely connecting them. In figs. 11 and 14 this becomes a broad ventral band; see p. 199.

Neither the "*Kirkbya annectens*" of 1885, nor the form once regarded as its "variety" *bipartita*, with its three lobes and three ridges (Ann. Mag. Nat. Hist., *loc. cit.*, figs. 8 *a*, *b*), show a central pit (which is obsolete in some *Kirkbyæ*); but the outline and the beridged surface agree with the features of *K. oblonga*; and ridges become special features in *K. plicata*. Therefore the Kirkbyan alliance is evident, as well as the Beyrichian feature of lobulate surface. Hence its appellation as connecting the two genera. But further, in *Drepanella*,* Ulrich, 1890 (Journ. Cincinn. Soc. Nat. Hist., vol. xiii., p. 117), a strong curved ridge, variable in development, lies between the variously tubercled part of the surface and the ventral and end margins. In *Bollia*, a curved ridge on the ventral region unites the two lobular ridges; but is sometimes obsolescent, leaving the essentials of *Ulrichia* (two distinct tubercles) apparent.

In our "*Kirkbya annectens*" the two lobules are significant of an Ulrichian alliance; but modified by their deliquescence into mere swellings of the two sides of the medial sulcus, as in *Primitia*. If the valves were furnished with a marginal fringe and with a dorsal ridge (as well as the sub-central longitudinal ridge), *S. annectens* would come within the limits of our *Beyrichiopsis*, Geol. Mag., 1886, p. 434. Indeed its alliance with this genus seems to be stronger than with any other.

In more than one direction, then, the name *annectens* has a significant meaning; and we therefore propose for this interesting Palæozoic Ostracod a new generic name, indicative of its connective character, viz. **Synaphe**, from συναφη, 'connection' or a 'joining together.'

This species is known to us from Cultra, Co. Down; Dromard, Co. Londonderry; and Largamore, Co. Mayo; also from Lanarkshire and Linlithgowshire, in Scotland; all in Lower Carboniferous beds.

28. **Ulrichia bituberculata** (M'Coy).

(Plate XII., figs. 20 *a*, *b*, *c*.)

1844.	*Cythere bituberculata*, .	M'COY, "Synop. Charact. Carb. Foss. Ireland," p. 165, pl. xxiii., fig. 10.
1866.	*Beyrichia bituberculata*,	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., p. 43; Quart. Journ. Geol. Soc., vol. xlii., p. 511; 1867, Trans. Geol. Soc. Glasgow, vol. ii., p. 220; 1887, Proceed. Geol. Assoc., vol. ix., p. 506.

This neat little sub-oblong bilobed form is comparable with *Kirkbya rigida*, Jones & Kirkby, 1885, Ann. Mag., ser. 5, vol. xv., p. 188, pl. iii., figs. 18 *a*, *b*, as

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* There is a *Drepanella* from Boghead, Scotland, in Dr. David Robertson's collection.

to general shape; but, having a pair of oval lobules, in the same relative position as the two narrow dorso-median ridges in that species, it cannot be the same. In its well-developed margins, though they are not so sharp, and its reticose ornaments, it shows its alliance with *K. rigida.** Its symmetrical pair of two isolated lobules, one on the front, and the other on the hinder moiety of the valve, remind us of the less uniform features in the "small bituberculate and punctate valve" of *Ulrichia Conradi*, Jones, from the Devonian of Canada (Quart. Journ. Geol. Soc., vol. xlvi., 1890, p. 544, woodcut, fig. 2). Here, however, the lobules are unequal and oblique, and the outline of the valve is different.

Doubtless our Irish specimens belong to *Ulrichia*, as defined in the Quart. Journ. Geol. Soc., vol. xlvi., p. 543 (1890), and vol. xlix., pp. 293 and 303. Hence we remove it from *Beyrichia* to that genus.

M'Coy's specimen came from Cultra, near Holywood, Co. Down. We have also seen this species from the locality "No. 11" ("Explan. Memoir of Sheets 37, 38, Geol. Survey Ireland," 1871, p. 17), near the Dalchoolin landing-place, a little north of Holywood.

In Scotland it occurs in the Lower Coal-measures at Orchard and Brockley, near Glasgow.

A good specimen from the "Upper Limestone (Carboniferous series)" at Williamswood, near Cathcart, 4 miles south of Glasgow, has been selected for illustration of this rare and interesting species, hitherto unfigured, except in M'Coy's somewhat unsatisfactory sketches.

29. **Bythocypris sublunata**, Jones & Kirkby.

1886. *B. sublunata*, . . JONES & KIRKBY, Geol. Mag., dec. 3, vol. iii., p. 250, pl. vii., figs. 9 *a*, *b*, 10, 11; Quart. Journ. Geol. Soc., vol. xlii., p. 512.

Very abundant both at Cultra and Carland; and agreeing well in the lunate form of carapace, thickness of shell, and the all-round overlap of the right valve by the left, with typical examples of the species.

This is another characteristic Lower Carboniferous species which is an abundant fossil in some localities of Roxburghshire; less so in Fife; but not at all rare in the Carboniferous shale underlying Secondary rocks, in Northamptonshire, as proved by the deep boring at Gayton.

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* This also is closely allied to *Ulrichia*.

30. **Bythocypris Phillipsiana** (Jones & Holl), var. **carbonica**, Jones & Kirkby.

1869. *Bairdia Phillipsiana*, . JONES & HOLL, Ann. Mag. Nat. Hist., ser. 4, vol. iii., p. 213, pl. xiv., fig. 7.
1885. *Bythocypris Phillipsiana*, var. *carbonica*, JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540.
1886. *Bythocypris Phillipsiana*, var. *carbonica*, JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 5, vol. xviii., p. 250, pl. vi., figs. 1*a*, *b*, 2*a*, *b*; Quart. Journ. Geol. Soc., vol. xlii., p. 512.

A little bean-shaped carapace, rather common among the Carland Ostracoda, comes nearer to the above species than to any other—so far at least as we can speak of its Carboniferous variety.

Some individuals, however, are more equal-ended than typical examples of the latter variety; others become very like *Cytherella* in the unequal size of the valves, amount of marginal overlap, and thickness of shell. So there may possibly be more than one species in this lot of small carapaces: a matter we cannot settle at present with the material before us.

The variety *carbonica* belongs to the Carboniferous rocks of Westmoreland, Northumberland, and Lanarkshire.

31. **Bythocypris** (?), sp.

It is necessarily difficult, if not impossible, to determine the generic standing of this simple cast from the shale at Carland. Its elongately sub-obvate shape reminds us of some valves formerly referred to *Cytherideis*,—to others belonging to *Macrocypris*, and others to *Bythocypris*; and of the last, especially one species named *B. testacella*, Jones (Ann. Mag. Nat. Hist., ser. 5, vol. xix., p. 186, pl. v., fig. 5 *a*), although our Carboniferous specimen is slimmer and more elegant, that is lower, with less dorsal convexity. In *Bythocypris* the left valve should be the largest, overlapping on the back; but this characteristic feature cannot be determined in this case, and the specimen must remain unnamed.

32. **Argillœcia æqualis**, Jones & Kirkby.

1882. *Cythere œqualis*, . . JONES & KIRKBY, MS. Quart. Journ. Geol. Soc., vol. xxxvi., pp. 573, 576, 588.
1885. *Argillœcia* ,, . . JONES & KIRKBY, Geol. Mag., dec. 3, vol. ii., p. 540.

1886.	*Argillœcia œqualis*, .	Jones & Kirkby, Ann. Mag. Nat. Hist., ser. 5, vol. xviii., p. 263, pl. ix., figs. 6*a*, *b*; Quart. Journ. Geol. Soc., vol xlii., p. 512.
1895.	*Argillœcia* (*Bythocypris*?) *œqualis*,	Jones & Kirkby, Ann. Mag. Nat. Hist., ser. 6, vol. xvi., pp. 455, 456, 460.

A single specimen comes from Cultra; and one problematical example from Carland. This species is found in the Lower Carboniferous strata of Fifeshire, Linlithgowshire, Ayrshire, Roxburghshire, Northumberland, Westmoreland, and Yorkshire.

33. **Macrocypris Jonesiana**, Kirkby.

1854.	*Bairdia gracilis* (part),	Reuss, Jahresb. Wetterauer Ges. für 1851–53, p. 65, fig. 3.
1858	,, *Jonesiana*, .	Kirkby, Ann. Mag. Nat. Hist., ser. 3, vol. ii., p. 432, pl. xi., figs. 1, 2, 2*a*.
1859.	*Cythere* (*Cytherideis*) *Jonesiana*,	Kirkby, Trans. Tyneside Field-Club, vol. iv., p. 151, pl. x., figs. 1, 2; and Jones, p. 168, pl. xi., figs. 24, 25 (vars.).
1882.	*Cythere Jonesiana*, . .	Kirkby, Quart. Journ. Geol. Soc., vol. xxxvi., p. 588.
1885.	*Macrocypris Jonesiana*,	Jones & Kirkby, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Geol. Mag., dec. 3, vol. iii., p. 251, pl. vii., fig. 12; and Quart. Journ. Geol. Soc., vol. xlii., p. 512.

This fine large form, from Carland, is probably a *Macrocypris*, allied to the apparently variable species *Macrocypris Jonesiana*. It is higher (broader) relatively in the middle, more arched on the back, and higher and more broadly rounded on the anterior (blunt) extremity, than Kirkby's typical figure. It is much more highly arched than Jones's figure, and its end more unequal. It is higher than the latest of the figures, and has not the hinder end so sharp and tapering.

This species is known from the Lower Carboniferous strata of both the South and the North of England, and from the West and the East of Scotland; also from the Permian of Durham and the Wetterau (now in the province of Hesse-Nassau).

34. **Krithe subreniformis**, sp. nov.

(Plate xii., figs. 17, 18*a*, *b*.)

In looking for published analogues of these specimens from the Cultra Shales (having none in our own possession), we readily find some neat, elongate, subcylindrical forms in Dr. G. S. Brady's monographs, which attract our notice, such as *Cythere teres*,[*] *Paradoxstoma Hibernicum*,[†] and *Krithe reniformis*[‡]. To this last species we have to refer the specimen before us as being almost identically the same in shape. There are, however, some slight differences.

Both Dr. Brady's *K. reniformis* and the Cultra specimens are elongate and sub-cylindrical, with straight hinge-line (rather more than half the entire length), and slightly incurved ventral border, neatly rounded posterior, and broader (higher) and somewhat obliquely rounded anterior extremity, valves convex, thin, and smooth.

In our fossils, however, the ventral incurve is more median, and their profile or edge-view has equally acute ends, and is not lanceolate as in the recent form. Neither the figured recent nor our fossil specimen is truly "reniform" in the usual acceptation of the term. Making the most of the slight differences in shape, thinking it best to give our specimens a specific name, and keeping within touch of G. S. Brady's species, we name ours *K. subreniformis.*

34A. **Krithe subreniformis, var. elongata.**

(Plate XII., fig. 19.)

Among the material from Carland we find the interesting specimen, fig. 19, which can only be an outgrown individual, or elongate variety of the foregoing *K. subreniformis.* It is somewhat more hollow on the ventral border, and its anterior moiety is not so high, but there are no essential differences apparent.

35. **Bairdia Hisingeri** (Münster), variety.

1830.	*Cythere Hisingeri*, . .	MÜNSTER, Jahrbuch für Miner., &c., p. 65, No. 18.
1858.	*Bairdia Schaurothiana*,	KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. ii., p. 329, pl. x., fig. 14; 1859, Trans. Tyneside Nat. Field-Club, vol. iv., p. 147, pl. ix., fig. 14 and woodcut 10.
1865.	,, *Hisingeri*, .	JONES & KIRKBY, Ann. Mag. Nat. Hist., ser. 3, vol. xv., p. 408, pl. xx., figs. 12 *a–c*; 1879, Quart. Journ. Geol. Soc., vol. xxxv., p. 570, pl. xxix., figs. 4–10; 1880, Quart. Journ. Geol. Soc., vol. xxxvi., p. 587; 1885, Geol. Mag., dec. 3, vol. ii., p. 540; 1895, Ann. Mag. Nat. Hist., ser. 6, vol. xvi., p. 454, pl. xxi., fig. 1.

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[*] Trans. Roy. Dub. Soc., ser. 2, vol. iv., 1889, p. 133, pl. xiv., figs. 36, 37.

[†] Ibid., p. 232, pl. xxi., figs. 15–17.

[‡] Ibid., p. 182, pl. xxi., figs. 23, 24.

An elongate narrow variety of this species occurs at Carland. It has the straight hinge-line, anterior and posterior dorsal slopes, obliquely rounded front, and sharply outstanding hinder end of the type, with a somewhat sinuous ventral border. But, instead of being stout, large, and sub-oblong, like the type, this specimen presents a neat, elongate, narrow, and subfusiform outline.

At first sight it might seem to be *B. subelongata* or *B. subcylindrica*, but it retains too much of the angular back of *B. Hisingeri* to be separated from that species.

36. **Bairdia**, sp.

An indeterminate sub-rhomboidal cast probably of a *Bairdia* occurs at Carland. It reminds us of *Bairdia præcisa*, Jones & Kirkby, Quart. Journ. Geol. Soc., vol. xxxv., 1879, p. 577, pl. xxxii., figs. 1–6, but it is longer and differently proportioned.

37. **Bairdia curta**, M'Coy.

(Plate xii. figs. 21*a*, *b*.)

1844.	*Bairdia curtus* [*ta*], .	M'Coy, "Synops. Char. Carb. Foss. Ireland," p. 166, pl. xxiii., fig. 15.
1859.	*Bairdia curta*, . . .	Kirkby, Tr. Tyneside N. F. C., vol. iv., pp. 142, 158.
1866.	,, ,, . . .	Jones & Kirkby, Ann. Mag. Nat. Hist., ser. 3, vol. xviii., pp. 41, 42; 1867, Trans. Soc. Geol. Glasgow, vol. ii., p. 221.
1870.	,, ,, . . .	Jones, Monthly Microsc. Journ., vol. iv., p. 185, pl. lxii., figs. 1*a*, *b*; vol. x., 1873, p. 77.
1879.	,, ,, (and vars.)	Jones & Kirkby, Quart. Jour. Geol. Soc., vol. xxxv., p. 567, pl. xxviii., figs. 1–8; 1886, vol. xlii., p. 513.
1885.	,, ,, . .	Jones & Kirkby, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Proceed. Geol. Assoc., vol. ix., p. 512.
1884.	,, ,, . .	Vine, Proc. Yorksh. Geol. Polyt. Soc., N. S., vol. viii., p. 231.

When first seen by us, Sir R. Griffith's specimen, figured by M'Coy, seemed to be almost, if not quite, the same as *B. plebeia*, Reuss, but after it was quite freed from its matrix, we recognized its distinct individuality.

This species is well known in the Carboniferous strata of England, Scotland,

and Ireland; but is not known to us as coming from anywhere abroad, although there are several closely allied forms. The specimen here figured is that from Granard, Co. Longford, which Dr. M'Coy referred to in his "Synop. Char. Carb. Foss., Ireland." The concentric marks on it are artificial, and indicate the stages of its clearance from the limestone matrix. The central mark is accidental.

38. **Bairdia plebeia**, Reuss.

1854. *Bairdia plebeia*,	Reuss, Jahresb. Wetterau. Gesell. for 1854, p. 67, fig. 5.
1855. *B. Geinitziana*,	Richter, Zeitsch. Deutsch. Geol. Gesell., vol. vii., p. 530, pl. xxvi., fig. 12.
1858. *B. plebeia*,	Kirkby, Ann. Mag. Nat. Hist., ser. 3, vol. ii., p. 324, pl. x., figs. 1–7.
1859. ,,	Kirkby & Jones, Trans. Tyneside Nat. Field-Club, vol. iv., pp. 141, 146, pl. ix., fig. 7.
1861. *Cythere (Bairdia) plebeia*,	Kirkby, Quart. Journ. Geol. Soc., vol. xvii., p. 308; 1862, Ann. Mag. Nat. Hist., ser. 3, vol. x., p. 203, pl. iv., figs. 5–10.
1867. *Cythere plebeia*,	Schmidt, Neues Jahrb., &c., p. 581, pl. vi., fig 26.
1875. *Bairdia* ,,	Jones & Kirkby, Ann. Mag. Nat. Hist., ser. 4., vol. xv., p. 56, pl. vi., figs. 6, 7; 1879, Quart. Journ. Geol. Soc., vol. xxxv., p. 569, pl. xxxviii., figs. 9–19; 1880, Quart. Journ. Geol. Soc., vol. xxxvi., p. 588; 1885, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 513; 1887, Proceed. Geol. Assoc., vol. ix., p. 512.

Valves having very much the shape of *Bairdia curta*, but blunt and not hatchet-shaped in front, higher in the back, and less sharply pointed behind.

This is a somewhat variable form, common in the Carboniferous and Permian strata of England, Scotland, and Germany. Some examples were found in the Carboniferous Limestone of Castle Espie, and a few, not well defined, in the shales at Cultra and Carland.

39. **Bairdia submucronata**, Jones & Kirkby.

1867. *Bairdia mucronata*, Reuss, var. *submucronata*, JONES & KIRKBY, Trans. Geol. Soc. Glasgow, vol. ii., p. 222.

1879. *Bairdia submucronata*, JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xxxv., p. 572, pl. xxix., figs. 12–18; 1885, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 513; 1887, Proceed. Geol. Assoc., vol. ix., p. 512.

Carapace sub-oval, with one end (posterior) eccentrically acute, the postero-ventral margin being much produced, with a more or less hollow curve above it, as usual in *Bairdia*. Rarely the anterior extremity has the Bairdian dorsal slope in front of a rather flat hinge-line.

Found at Castle Espie. Not rare in the Carboniferous Limestone of Scotland, England, and North Wales.

Some varieties have an approximate resemblance, but merely as to outline, to certain forms of *Beecherella*, Ulrich, 1891.

40. **Bairdia subelongata**, Jones & Kirkby.

1867. *Bairdia subcylindrica* (Münster), JONES & KIRKBY, Trans. Geol. Soc. Glasgow, vol. ii., p. 221.

1879. *Bairdia subelongata*, . JONES & KIRKBY, Quart. Journ. Geol. Soc., vol. xxxv., p. 573, pl. xxx., figs. 1–11, 16; 1880, Quart. Journ. Geol. Soc., vol. xxxvi., p. 587; 1885, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 513; 1887, Proc. Geol. Assoc., vol. ix., p. 512.

Subcylindrical; rounded in front; acute at the postero-ventral end. Dorsal and ventral borders generally parallel, though varying slightly as to curvatures in individuals.

Common in the Carboniferous Limestone series of Scotland; found also at Great Orme's Head, North Wales, and at Castle Espie.

41. **Bairdia brevis**, Jones & Kirkby.

1867. *Bairdia brevis*, . . JONES & KIRKBY, Trans. Geol. Soc. Glasgow, vol. ii., p. 221; 1879, Quart. Journ. Geol. Soc., vol. xxxv., p. 575, pl. xxxi., figs. 1–8; 1880, Quart. Journ. Geol. Soc., vol. xxxvi., p. 587; 1885, Geol. Mag., dec. 3, vol. ii., p. 540; 1886, Quart. Journ. Geol. Soc., vol. xlii., p. 513; 1887, Proc. Geol. Assoc., vol. ix., p. 512.

Subrhomboidal and variable, sometimes obliquely acute-oval; short and thick.

Not rare in the Carboniferous Limestone of England and Scotland. Found also in that formation at Castle Espie.

NOTES ON THE SPECIES FROM CASTLE ESPIE.

The specimens from the red Carboniferous Limestone of Castle Espie are not in good preservation, though most of them are carapaces,—not single valves. Many of them are distorted by pressure, and none show the true surface. This renders it difficult in many cases to say to what species the specimens belong, further than that they are *Bairdiæ*. Most of them are of this genus.

Bairdia plebeia, Reuss, is the most common; and it occurs both in its typical form, and in one of its more elongate varieties.

B. submucronata, Jones & Kirkby, is represented by a less number of individuals; the posterior extremity of some is drawn out somewhat after the fashion of *B. mucronata*, Reuss.

B. brevis, Jones & Kirkby, is present, but very sparingly.

B. subelongata, Jones & Kirkby, also occurs rarely, in full-sized examples.

The only other determinable form in this lot is *Cytherella recta*, Jones & Kirkby, of which there is a single well-grown carapace; see above, page 178.

NOTE.—27* SYNAPHE ANNECTENS, var. CONFUSA, nov.

(Plate XII., figs. 11 and 14.)

In some specimens of *Synaphe*, from Cultra, the thin longitudinal ridge is replaced by a broad, swollen, ventral band, connecting the two tubercles, and giving a subquadrate shape to the dorso-central depression. This form has some relationship to "*Ulrichia? confluens*," Ulrich (Journ. Cinn. Soc. N. H., vol. xiii., part 2, 1891, p. 203, pl. xii., fig. 11), from the Carboniferous Shales of Kentucky.

TABLE OF SPECIMENS AND LOCALITIES.

	Billatraherhead, Donegal.	Bundovan, Donegal.	Dromard, Londonderry.	Cullivin, Londonderry.	Carland, Tyrone.	Aghnaglogh, Tyrone.	Fermanagh.	Cultra, Down.	Castle Espie, Down.	Granard, Longford.	Bunowna, Sligo.	Larganmore. Mayo.	Cork.	Plates.	Figures.
1. **Cytherella**—valida, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
2. ,, extuberata, J. & K.,	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
3. ,, attenuata, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
4. ,, incurvescens, sp. nov.,	—	—	—	—	—	—	—	×	—	—	—	—	—	XI.	1–5 & 6 ?
5. ,, simplex, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
6. ,, recta, J., K., & B.,	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—
7. ,, Hibernica, J., K., & B.,	—	—	—	—	—	—	—	×	—	—	—	—	—	XI.	7*a*, *b*.
8. **Leperditia**—Okeni (Münster),	—	—	—	—	×	—	—	—	—	—	—	—	—	XI.	8–10.
9. ,, suborbiculata (Münster),	—	—	—	—	×	—	—	—	—	—	—	—	—	XI.	11.
10. ,, Scotoburdigalensis (Hibbert),	—	—	×	—	—	—	—	×	—	—	—	—	—	XI.	12.
11. ,, subrecta (Portlock),	×	—	×	×	—	×	×	×	—	—	×	×	—	XI.	13, 14.
12. ,, inornata (M'Coy),	—	×	—	—	—	—	—	—	—	—	—	—	—	XI. XII.	15, 16. 1–3.
13. ,, Wrightiana, sp. nov.,	—	—	—	—	×	—	—	—	—	—	—	—	—	XII.	4, 5.
14. ,, acuta, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
15. ,, rhombica, sp. nov.,	—	—	—	—	×	—	—	—	—	—	—	—	—	XII.	6.
16. ,, compressa, J & K.,	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
17. ,, amygdalina (M'Coy),	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
18. **Beyrichia**—craterigera, Brady,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
19. ,, Hibernica, sp. nov.,	—	—	—	—	—	—	—	×	—	—	—	—	—	XII.	7*a*, *b*.
20. ,, gigantea, J. & K.,	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—
21. **Kirkbya**—Permiana, Jones,	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
22. ,, spiralis, J. & K.,	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
23. ,, plicata, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
24. ,, costata (M'Coy),	—	—	—	—	—	—	—	×	—	—	—	—	—	—	—
25. **Beyrichiopsis**—fimbriata, J. & K.,	—	—	—	—	×	—	—	×(?)	—	—	—	—	—	—	—
26. ,, fortis, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
27. **Synaphe**—annectens, J. & K.,	—	—	×	—	—	—	—	×	—	—	—	×	—	XII.	8-10, 12, 13, 15
28. **Ulrichia**—bituberculata (M'Coy),	—	—	—	—	—	—	—	×	—	—	—	—	—	XII.	20*a*, *b*.
29. **Bythocypris**—sublunata, J. & K.,	—	—	—	—	×	—	—	×	—	—	—	—	—	—	—
30. ,, Phillipsiana, var. carbonica, J. & K.,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
31. ,, sp.	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
32. **Argillœcia**—æqualis, J. & K.,	—	—	—	—	×	—	—	×	—	—	—	—	—	—	—
33. **Macrocypris**—Jonesiana, Kirkby,	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—
34. **Krithe**—subreniformis, sp. nov.,	—	—	—	—	—	—	—	×	—	—	—	—	—	XII.	17, 18*a*, *b*.
34.* ,, Var. elongata, nov.,	—	—	—	—	×	—	—	—	—	—	—	—	—	XII.	19.
35. **Bairdia**—Hisingeri (Münster),	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—
36. ,, sp.	—	—	—	—	×	—	—	—	×	—	—	—	—	—	—
37. ,, curta, M'Coy,	—	—	—	—	—	—	—	—	—	×	—	—	—	XII.	21*a*, *b*.
38. ,, plebeia, Reuss,	—	—	—	—	×	—	—	×	×	—	—	—	—	—	—
39. ,, submucronata, J. & K.,	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—
40. ,, subelongata, J. & K.,	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—
41. ,, brevis, J. & K.,	—	—	—	—	—	—	—	—	×	—	—	—	—	—	—

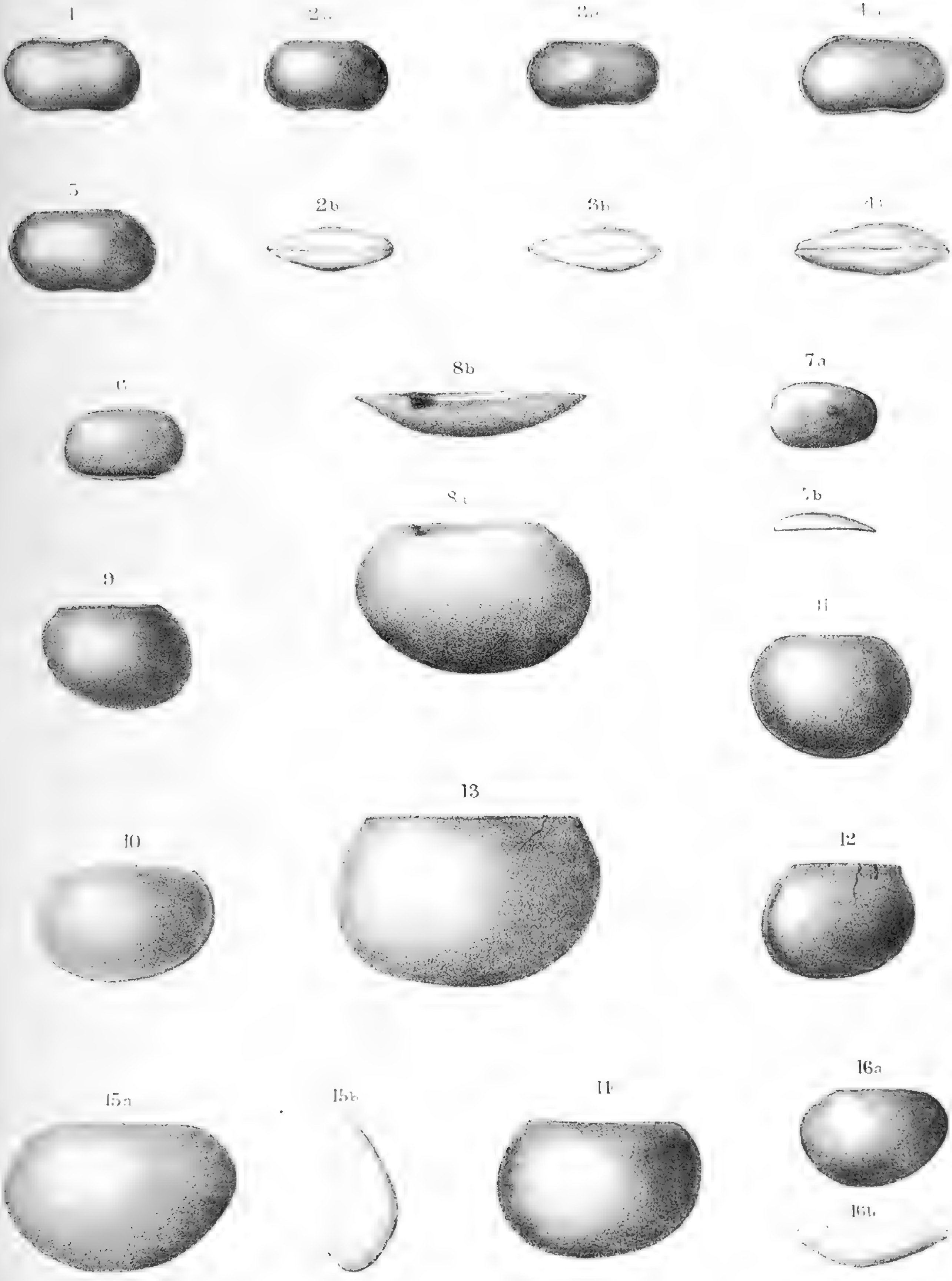
NOTE.—See page 199 for 27*, *Synape annectens*, var. *confusa*, nov., Pl. XII., figs. 11 and 14.

EXPLANATION OF PLATE XI.

PLATE XI.

[*All the Figures are magnified about* 25 *diameters.*]

Figure		Locality.
1.	*Cytherella incurvescens*, sp. nov., carapace showing the left valve,	Cultra.
2.	,, ,, ,, (*a*) carapace showing the left valve,	,,
	,, ,, ,, (*b*) edge view,	,,
3.	,, ,, ,, (*a*) carapace showing the left valve,	,,
	,, ,, ,, (*b*) edge view,	,,
4.	,, ,, ,, (*a*) carapace showing the left valve,	,,
	,, ,, ,, (*b*) edge view,	,,
5.	,, ,, ,, carapace showing the left valve,	,,
6.	,, sp. carapace showing the left valve,	,,
7.	*Cytherella Hibernica*, J. & K., (*a*) right valve,	,,
	,, ,, ,, (*b*) ventral view,	,,
8.	*Leperditia Okeni*, (Münster), (*a*) left valve,	Carland.
	,, ,, ,, (*b*) edge view,	,,
9.	,, ,, ,, left valve,	,,
10.	,, ,, ,, right valve,	,,
11.	*Leperditia suborbiculata* (Münster), carapace showing the left valve,	,,
12.	*Leperditia Scotoburdigalensis* (Hibbert), carapace showing the right valve,	Dromard.
13.	*Leperditia subrecta* (Portlock), right valve,	Cultra.
14.	,, ,, ,, right valve,	,,
15.	*Leperditia inornata* (M'Coy), (*a*) right valve,	Bundoran.
	,, ,, ,, (*b*) end view,	,,
16.	,, ,, ,, (*a*) right valve,	,,
	,, ,, ,, (*b*) ventral view,	,,



J.W.K. del.
F.C. Knight lith.

CARBONIFEROUS OSTRACODA, IRELAND.

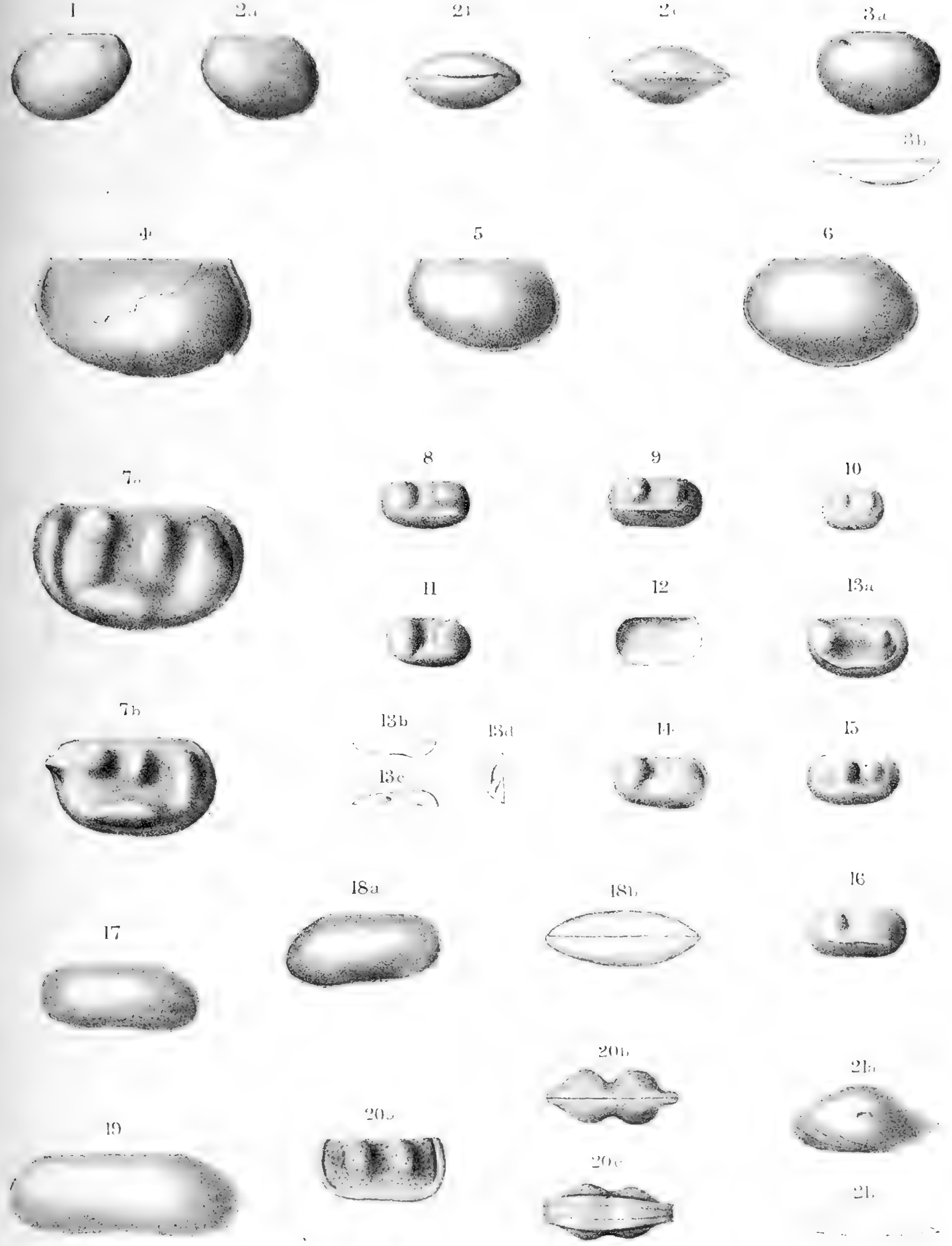
West, Newman imp.

EXPLANATION OF PLATE XII.

PLATE XII.

[*All the Figures, except fig.* 21, *are magnified about* 25 *diameters.*]

Figure			Locality.
1.	*Leperditia inornata,* (M'Coy),	right valve,	Bundoran.
2.	,, ,, ,,	(*a*) carapace showing the left valve,	,,
	,, ,, ,,	(*b*) dorsal view,	,,
	,, ,, ,,	(*c*) ventral view,	,,
3.	,, ,, ,,	(*a*) left valve,	,,
	,, ,, ,,	(*b*) ventral view,	,,
4.	*Leperditia Wrightiana,* sp. nov.,	left valve,	Carland.
5.	,, ,, ,,	left valve,	,,
6.	*Leperditia rhombica,* sp. nov.,	left valve,	,,
7.	*Beyrichia Hibernica,* sp. nov.,	(*a*) left valve,	Cultra.
	,, ,, ,,	(*b*) left valve,	,,
8.	*Synaphe annectens,* J. & K.,	left valve,	,,
9.	,, ,, ,,	left valve,	,,
10.	,, ,, ,,	right valve,	,,
11.	,, ,, var. *confusa,*	nov., left valve,	,,
12.	,, ,, J. & K.,	left valve, showing the interior,	,,
13.	,, ,, ,,	(*a*) left valve,	,,
	,, ,, ,,	(*b*) ventral edge (reserved),	,,
	,, ,, ,,	(*c*) dorsal edge (reserved),	,,
	,, ,, ,,	(*d*) end view,	,,
14.	,, ,, var. *confusa,*	nov., left valve,	,,
15.	,, ,, J. & K.,	right valve,	,,
16.	,, ,, ,,	left valve,	,,
17.	*Krithe subreniformis,* sp. nov.,	right valve,	,,
18.	,, ,, ,,	(*a*) carapace showing the left valve,	,,
	,, ,, ,,	(*b*) edge view,	,,
19.	,, ,, var. *elongata,*	right valve,	Carland.
20.	*Ulrichia bituberculata* (M'Coy),	(*a*) carapace showing the left valve,	Williamswood.
	,, ,, ,,	(*b*) dorsal edge,	,,
	,, ,, ,,	(*c*) ventral edge,	,,
21.	*Bairdia curta,* M'Coy,	(*a*) left valve, edge view, } × 15,	Granard, Longford.
	,, ,, ,,		



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[Read November 18, 1896.]

If V stand for $\frac{x^2}{x^2+y^2+z^2-a^2}+\frac{y^2}{x^2+y^2+z^2-b^2}+\frac{z^2}{x^2+y^2+z^2-c^2}$, then the equation $V=0$ denotes the surface, the radius vector of which represents the wave velocity in Fresnel's theory; the equation $V=0$ may be written in the form

$$I^2+\sigma_1\sigma_2\sigma_3\sigma_4=0,$$

where I stands for

$$c^2x^2(a^2+b^2)+2a^2c^2y^2+a^2(b^2+c^2)z^2-(a^2+c^2)(x^2+y^2+z^2)^2,$$

and σ_1 for $\quad cx\sqrt{a^2-b^2}+az\sqrt{b^2-c^2}+\sqrt{a^2-c^2}\,(x^2+y^2+z^2),$

σ_2 for $\quad cx\sqrt{a^2-b^2}-az\sqrt{b^2-c^2}+\sqrt{a^2-c^2}\,(x^2+y^2+z^2),$

σ_3 for $\quad -cx\sqrt{a^2-b^2}+az\sqrt{b^2-c^2}+\sqrt{a^2-c^2}\,(x^2+y^2+z^2),$

and σ_4 for $\quad cx\sqrt{a^2-b^2}+az\sqrt{b^2-c^2}-\sqrt{a^2-c^2}\,(x^2+y^2+z^2)$;

from which it follows that $\sigma_1=0$ touches the surface $V=0$ where the sphere meets the surface $I=0$. Now it is clear that the curve of intersection of $\sigma_1=0$ with $I=0$ is the curve of intersection of $\sigma_1=0$ with $C=0$, where C stands for

$$x^2(b^2-c^2)+y^2(a^2-c^2)+z^2(a^2-b^2)-xz(a^2+c^2)\sqrt{(a^2-b^2)(b^2-c^2)}\,/\,ac.$$

Again, the intersection of $\sigma_1=0$ and $C=0$ is $L=0$ and $M=0$ for

$$acC+LM=\sigma_1 ac\sqrt{a^2-c^2},$$

where L stands for $\quad cx\sqrt{a^2-b^2}+az\sqrt{b^2-c^2},$

and M for $\quad ax\sqrt{a^2-b^2}+cz\sqrt{b^2-c^2}+ac\sqrt{a^2-c^2}.$

Similar results obtain for the other three spheres.

The above results were at first obtained geometrically by the doctrine of inversion applied to the results obtained in my other Paper,* for the surface $V=0$

---

* Proc. Roy. Dublin Society, Vol. VIII., Pt. v., No. 48, p. 381.

is the inverse of the polar reciprocal of $W=0$. Use was also made of the principles of the cyclic sections of a cone of the second order. There is a circular section of $C=0$ parallel to $L=0$, which is one of the four circles on the reciprocal of $W=0$; its equation is

$$L' \equiv cx\sqrt{a^2-b^2}+az\sqrt{b^2-c^2}+\sqrt{a^2-c^2}=0.$$

This latter section is the inverse of $M=0$, and they both lie on a sphere; its equation is

$$acC+L'M=ac\,(a^2-c^2)\,S_1=0,$$

where S_1 is $$x^2+y^2+z^2+1+x\left(c+\frac{1}{c}\right)\sqrt{\frac{a^2-b^2}{a^2-c^2}}+z\left(a+\frac{1}{a}\right)\sqrt{\frac{b^2-c^2}{a^2-c^2}};$$

and the "power" of the origin with reference to $S_1=0$ is unity as it ought to be. If α, β, γ be the coordinates of the centre of the sphere, then

$$\alpha=\tfrac{1}{2}\left(c+\frac{1}{c}\right)\sqrt{\frac{a^2-b^2}{a^2-c^2}},\quad \beta=0,$$

and $$\gamma=\tfrac{1}{2}\left(a+\frac{1}{a}\right)\sqrt{\frac{b^2-c^2}{a^2-c^2}};$$

and if R be the radius, then

$$\alpha^2+\gamma^2-R^2=1.$$

The plane $M=0$ cuts $V=0$ in a circle, and the sphere $\sigma_1=0$ touches $V=0$ all along this circle, so that if a tangent plane be drawn to $V=0$ at every point on this circle, the developable so generated is a cone of the second order and of revolution. This cone stands out or away from the origin, and the portion of the surface V in its neighbourhood is a small protuberance corresponding to what Professor Tait calls a "basin" on the wave surface. There are, of course, three other real cones—in fact, as there are sixteen "basins" on the wave surface, there are sixteen corresponding cones touching $V=0$. We shall only notice the case corresponding to the four imaginary "basins" at infinity on the wave surface. The equation $V=0$ can be written in the form $P_1P_2P_3P_4+J^2=0$ where J stands for

$$x^2(b^2+c^2)+y^2(c^2+a^2)+z^2(a^2+b^2)-2(x^2+y^2+z^2)^2,$$

P_1 for $$x\sqrt{c^2-b^2}+y\sqrt{a^2-c^2}+z\sqrt{b^2-a^2},$$

P_2 for $$x\sqrt{c^2-b^2}-y\sqrt{a^2-c^2}+z\sqrt{b^2-a^2},$$

P_3 for $$-x\sqrt{c^2-b^2}+y\sqrt{a^2-c^2}+z\sqrt{b^2-a^2},$$

and P_4 for $$x\sqrt{c^2-b^2}+y\sqrt{a^2-c^2}-z\sqrt{b^2-a^2};$$

that is to say, the imaginary spheres degenerate in this case to imaginary planes.

These four planes occur also if we write the equation of the surface thus:

$$(x^2+y^2+z^2)^3-(x^2+y^2+z^2)\left[(b^2+c^2)\,x^2+(c^2+a^2)\,y^2+\overline{a^2+b^2}\,z^2\right]$$
$$+\,b^2c^2x^2+c^2a^2y^2+a^2b^2z^2=0,$$

or
$$\rho^4-\rho^2\left[(b^2+c^2)\,l^2+(c^2+a^2)\,m^2+(a^2+b^2)\,n^2\right]+b^2c^2l^2+c^2a^2m^2+a^2b^2n^2=0,$$

where l, m, and n are direction cosines. Now expressing the condition that both values of ρ^2 are equal, we have the locus

$$\left[(b^2+c^2)\,x^2+(c^2+a^2)\,y^2+(a^2+b^2)\,z^2\right]^2-4\,(x^2+y^2+z^2)\,(b^2c^2x^2+c^2a^2y^2+a^2b^2z^2)=0,$$

and the left-hand side of this equation is the product $P_1P_2P_3P_4$ with the sign changed. The singular points on $V=0$ are easily determined, and also the equation of a singular tangent cone at a singular point.

It is well-known that $V=0$ is the first positive pedal of $W=0$; it is required to find the first positive pedal of $V=0$; that is, the second positive pedal of $W=0$; that is, find the envelope of the sphere

$$\left(x-\frac{x'}{2}\right)^2+\left(y-\frac{y'}{2}\right)^2+\left(z-\frac{z'}{2}\right)^2=\frac{x'^2+y'^2+z'^2}{4},$$

or of
$$x^2+y^2+z^2-xx'-yy'-zz'=0,$$

where $x'y'z'$ are connected by the relation

$$\frac{x'^2}{t'^2-a^2}+\frac{y'^2}{t'^2-b^2}+\frac{z'^2}{t'^2-c^2}=0,$$

where $t'^2=x'^2+y'^2+z'^2$; then

$$-\,x=\lambda\left[\frac{2x'}{t'^2-a^2}-\left\{\frac{x'^2}{(t'^2-a^2)^2}+\frac{y'^2}{(t'^2-b^2)^2}+\frac{z'^2}{(t'^2-c^2)^2}\right\}2x'\right]$$

with similar equations for y and z. Now it is known that

$$\frac{x'}{t'^2-a^2}=\frac{\xi}{r^2-a^2},\qquad\frac{y'}{t'^2-b^2}=\frac{\eta}{r^2-b^2},\qquad\frac{z'}{t'^2-c^2}=\frac{\zeta}{r^2-c^2},$$

where ξ, η, ζ, and r, on $W=0$ correspond to $x'y'z't'$ on $V=0$. Hence

$$-\,x=2\lambda x'\left[\frac{1}{t'^2-a^2}-\frac{1}{r^2-t'^2}\right]$$

with two other equations. Now putting $t^2\equiv x^2+y^2+z^2$, and remembering that $tr=t'^2$, from the doctrine of pedal surfaces, it follows that

$$-\,x=2\lambda x'\left[\frac{1}{t'^2-a^2}-\frac{t^2}{t'^4-t^2t'^2}\right],$$

or
$$x=2\lambda x'\left[\frac{2t^2t'^2-a^2t^2-t'^4}{(t'^2-a^2)(t'^2-t^2)\,t'^2}\right],$$

with two other equations, multiplying the first by x', the second by y', and the third by z', and adding, we have

$$t^2 = 2t^2\lambda/(t'^2 - t^2). \quad \text{Hence } 2\lambda = t'^2 - t^2;$$

$$\therefore \quad x' = \frac{xt'^2(t'^2 - a^2)}{2t^2 t'^2 - a^2 t^2 - t'^4}.$$

Substituting this value of x' in $x^2 + y^2 + z^2 - xx' - yy' - zz' = 0$, and similarly for y' and z', we have

$$\frac{x^2t'^2(t'^2 - a^2)}{2t^2t'^2 - a^2t^2 - t'^4} + \frac{y^2t'^2(t'^2 - b^2)}{2t^2t'^2 - b^2t^2 - t'^4} + \frac{z^2t'^2(t'^2 - c^2)}{2t^2t'^2 - c^2t^2 - t'^4} = t^2,$$

or

$$\frac{x^2(2t'^2 - a^2)}{2t^2t'^2 - a^2t^2 - t'^4} + \frac{y^2(2t'^2 - b^2)}{2t^2t'^2 - b^2t^2 - t'^4} + \frac{z^2(2t'^2 - c^2)}{2t^2t'^2 - c^2t^2 - t'^4} = 0; \tag{1}$$

and if we substitute $x'y'z'$ in $x'^2/(t'^2 - a^2) + \&c. = 0$, we get

$$\frac{x^2(t'^2 - a^2)}{(2t^2t'^2 - a^2t^2 - t'^4)^2} + \frac{y^2(t'^2 - b^2)}{(2t^2t'^2 - b^2t^2 - t'^4)^2} + \frac{z^2(t'^2 - c^2)}{(2t^2t'^2 - c^2t^2 - t'^4)^2} = 0. \tag{2}$$

Now (2) is the derived equation of (1) with respect to t'. It follows, therefore, that putting $t'^2 \equiv \theta$ that the second positive pedal of $W = 0$ is written down by equating to zero the discriminant of

$$\frac{x^2}{t^2 - A^2} + \frac{y^2}{t^2 - B^2} + \frac{z^2}{t^2 - C^2} = 0, \tag{3}$$

regarded as a quintic in θ, and

$$A^2 \text{ stands for } \frac{\theta^2}{2\theta - a^2}, \quad B^2 \text{ for } \frac{\theta^2}{2\theta - b^2}, \quad \text{and } C^2 \text{ for } \frac{\theta^2}{2\theta - c^2};$$

we can also, by taking the inverse of this second pedal, obtain the polar reciprocal of $V = 0$. Now, geometrically, the polar reciprocal of $V = 0$ is the first negative pedal of the polar reciprocal of $W = 0$. Hence, changing a^2 into $\frac{1}{a^2}$, and similarly for b^2 and c^2, and putting X for $\frac{x}{x^2 + y^2 + z^2}$ in (3), and similarly for Y and Z, it appears that the first negative pedal of $W = 0$, that is, of Fresnel's Wave Surface, is obtained by equating to zero the discriminant of

$$\frac{\alpha^2 x^2}{x^2 + y^2 + z^2 - \alpha^2} + \frac{\beta^2 y^2}{x^2 + y^2 + z^2 - \beta^2} + \frac{\gamma^2 z^2}{x^2 + y^2 + z^2 - \gamma^2} = 0, \tag{4}$$

regarded as a quantic in ϕ, where $a^2\alpha^2$ stands for $2a^2\phi - \phi^2$, $b^2\beta^2$ for $2b^2\phi - \phi^2$, and $c^2\gamma^2$ for $2c^2\phi - \phi^2$.

An ellipsoid is also a surface whose polar reciprocal (with reference to a concentric sphere) is of the same type as itself; hence it would follow, geometrically, that its negative pedal may be written down from its second positive pedal. The determination of the second positive pedal of the ellipsoid is the same thing as finding the envelope of the sphere

$$x^2 + y^2 + z^2 - xx' - yy' - zz' = 0,$$

where
$$(x'^2 + y'^2 + z'^2)^2 = a^2x'^2 + b^2y'^2 + c^2z'^2.$$

Now, proceeding in precisely the way adopted above, it will appear, without difficulty, that the first positive pedal of Fresnel's "Surface of Elasticity" is obtained by equating to zero the discriminant of

$$\frac{x^2}{2 - a^2\theta} + \frac{y^2}{2 - b^2\theta} + \frac{z^2}{2 - c^2\theta} - \theta\,(x^2 + y^2 + z^2)^2 = 0, \qquad (5)$$

regarded as a quartic in θ. This also gives the polar reciprocal of the same surface, and changing a^2 into $\frac{1}{a^2}$, &c., and writing X for $\frac{x}{x^2 + y^2 + z^2}$, it appears that the negative pedal of the ellipsoid is obtained by equating to zero the discriminant of

$$\frac{x^2}{2 - \frac{\theta}{a^2}} + \frac{y^2}{2 - \frac{\theta}{b^2}} + \frac{z^2}{2 - \frac{\theta}{c^2}} - \theta = 0, \qquad (6)$$

regarded as a quartic in θ. This is the result obtained, otherwise originally, by Professor Cayley. See Salmon's "Surfaces," Art. 517. Moreover, in the same way as above, the first positive pedal of the surface

$$(x^2 + y^2 + z^2)^n = a^2x^2 + b^2y^2 + c^2z^2$$

is written down by equating to zero the discriminant of

$$\frac{x^2(n-1)}{n - a^2\theta^{n-1}} + \frac{y^2(n-1)}{n - b^2\theta^{n-1}} + \frac{z^2(n-1)}{n - c^2\theta^{n-1}} - \theta(x^2 + y^2 + z^2)^2 = 0, \qquad (7)$$

regarded as a quantic in θ. The result also provides the polar reciprocal of the same surface for all values of n by putting X for $x\,/\,(x^2 + y^2 + z^2)$, and similarly for y and z. In all such cases the traces of the several surfaces on the principal planes may be directly obtained after the manner indicated in Salmon's "Surfaces," Art. 202, Ex. 2, page 157.

Again, the parallel surface to Fresnel's surface of elasticity may be obtained by the same method: this is the same thing as determine the envelope of the sphere

$$\left(x - \frac{x'}{2}\right)^2 + \left(y - \frac{y'}{2}\right)^2 + \left(z - \frac{z'}{2}\right)^2 = \left(k + \frac{t}{2}\right)^2,$$

where
$$\left(\frac{x'}{a}\right)^2 + \left(\frac{y'}{b}\right)^2 + \left(\frac{z'}{c}\right)^2 = 1, \quad t \equiv \sqrt{x'^2 + y'^2 + z'^2},$$

and k the normal distance between the parallel surfaces, or find the envelope of

$$x^2 + y^2 + z^2 - xx' - yy' - zz' = kt + k^2, \tag{8}$$

where

$$\frac{x'^2}{a^2} + \frac{y'^2}{b^2} + \frac{z'^2}{c^2} = 1.$$

Hence we get

$$x + \frac{kx'}{t} = \frac{\lambda x'}{a^2},$$

$$y + \frac{ky'}{t} = \frac{\lambda y'}{b^2},$$

$$z + \frac{kz'}{t} = \frac{\lambda z'}{c^2}.$$

Hence

$$xx' + yy' + zz' + kt = \lambda = x^2 + y^2 + z^2 - k^2;$$

$$\therefore\quad x' = \frac{x}{\dfrac{\lambda}{a^2} - \dfrac{k}{t}}, \text{ \&c.}$$

Substituting in (8) we get

$$\frac{a^2x^2}{\lambda - \dfrac{ka^2}{t}} + \frac{b^2y^2}{\lambda - \dfrac{kb^2}{t}} + \frac{c^2z^2}{\lambda - \dfrac{kc^2}{t}} + kt = x^2 + y^2 + z^2 - k^2.$$

Hence

$$\frac{a^2x^2}{1 + \theta a^2} + \frac{b^2y^2}{1 + \theta b^2} + \frac{c^2z^2}{1 + \theta c^2} - \frac{k^2}{\theta} = (x^2 + y^2 + z^2 - k^2)^2. \tag{9}$$

Again, if we substitute in $t^2 = x'^2 + y'^2 + z'^2$, we get

$$\frac{a^4x^2}{(1+\theta a^2)^2} + \frac{b^4y^2}{(1+\theta b^2)^2} + \frac{c^4z^2}{(1+\theta c^2)^2} - \frac{k^2}{\theta^2} = 0, \tag{10}$$

which is the derived equation of (9) with regard to θ. Hence the parallel surface is obtained by equating to zero the discriminant of (9) considered as a quartic in θ, and the application of the method employed in Salmon's "Surfaces," Art. 206, to the equation (9), reduces to a definite algebraic problem the determination of the "surface of centres" of the surface of elasticity. Again, the same method gives us the parallel surface to an ellipsoid (without using the Calculus of Invariants and Covariants), in fact, this is the same thing as the determination of the envelope of

$$(xx' + yy' + zz' - k)^2 = a^2x'^2 + b^2y'^2 + c^2z'^2, \quad \text{where} \quad x'^2 + y'^2 + z'^2 = 1.$$

Proceeding precisely as before, it will be seen without trouble that the result is obtained by equating to zero the discriminant of

$$\frac{x^2}{\theta + a^2} + \frac{y^2}{\theta + b^2} + \frac{z^2}{\theta + c^2} = 1 + \frac{k^2}{\theta}, \tag{11}$$

regarded as a quartic in θ. This is the equation obtained otherwise by Salmon, see "Surfaces," Art. 202, Ex. 2. If we had defined the parallel surface as the envelope of the sphere

$$(x-x')^2+(y-y')^2+(z-z')^2=k^2, \quad \text{where} \quad \frac{x'^2}{a^2}+\frac{y'^2}{b^2}+\frac{z'^2}{c^2}=1,$$

the application of the same method leads without trouble to the solution as equating to zero the discriminant of

$$\frac{4a^2x^2}{2a^2-\theta}+\frac{4b^2y^2}{2b^2-\theta}+\frac{4c^2z^2}{2c^2-\theta}=\theta+2(x^2+y^2+z^2-k^2). \tag{12}$$

This equation is equivalent to (11), but it presents the parallel surface to us in an interesting way, for if, following Mr. W. Roberts (Salmon's "Surfaces," Art. 518), we put $x^2+y^2+z^2=k^2$, and then change x into $x/2$, y into $y/2$, and z into $z/2$, we have Professor Cayley's equation (6) given above for the negative pedal.

The determination of the parallel surface to the "surface of elasticity" may also be effected in the following way. Find the envelope of

$$2xx'+2yy'+2zz'=x^2+y^2+z^2-k^2+x'^2+y'^2+z'^2,$$

where $$(x'^2+y'^2+z'^2)^2=a^2x'^2+b^2y'^2+c^2z'^2.$$

Differentiating we have
$$\begin{aligned} x-x' &= \lambda x'(2t'^2-a^2),\\ y-y' &= \lambda y'(2t'^2-b^2),\\ z-z' &= \lambda z'(2t'^2-c^2) \end{aligned}$$
[where $t'^2=x'^2+y'^2+z'^2$].

Also put $M=x^2+y^2+z^2-k^2$. Hence $xx'+yy'+zz'-t'^2=\lambda t'^4$,

which is the same as $2\lambda t'^4=M-t'^2$. Hence $\lambda=\dfrac{M-t'^2}{2t'^4}$.

Hence $x-x'=x'\dfrac{(2t'^2-a^2)(M-t'^2)}{2t'^4}$ and $x'=\dfrac{2x}{\theta(a^2+2M-a^2M\theta)}$, where $\theta=\dfrac{1}{t'^2}$,

and now substituting for x' in the given equations, we have the two equations

$$\frac{4x^2}{a^2+2M-a^2\theta M}+\frac{4y^2}{b^2+2M-b^2\theta M}+\frac{4z^2}{c^2+2M-c^2\theta M}=\theta M+1, \tag{13}$$

and
$$\frac{4x^2a^2}{(a^2+2M-a^2\theta M)^2}+\frac{4b^2y^2}{(b^2+2M-b^2\theta M)^2}+\frac{4c^2z^2}{(c^2+2M-c^2\theta M)^2}=1. \tag{14}$$

Now the second is the derived of the first with reference to θ. Hence the answer is the discriminant of (13) equated to zero. Now if in (13) we put $k^2=x^2+y^2+z^2$, that is, $M=0$, and change x into $x/2$, y into $y/2$, and z into $z/2$, we get the ellipsoid as we ought. We could *not* have done likewise with the equation (9). Also following Mr. W. Roberts (13) enables us to obtain the negative pedal with reference to any origin of the "surface of elasticity," and also gives us with reference to any origin, the negative pedal of its parallel. If we apply this method of finding envelopes to the determination of the envelope of the plane

$$xx' + yy' + zz' = x'^2 + y'^2 + z'^2, \quad \text{where} \quad \frac{x'^2}{t'^2 - a^2} + \frac{y'^2}{t'^2 - b^2} + \frac{z'^2}{t'^2 - c^2} = 0,$$

t'^2 being $x'^2 + y'^2 + z'^2$, we find two equations $A\theta + B = 0$, and $C\theta + D = 0$, where $A = 0$ and $B = 0$ are the two well-known Cartesian Equations of the Wave Surface, and $C = 0$ and $D = 0$ are

$$\frac{x^2}{(r^2 - a^2)^2} + \frac{y^2}{(r^2 - b^2)^2} + \frac{z^2}{(r^2 - c^2)^2} = \frac{1}{r^2 - p^2},$$

and

$$\frac{a^2 x^2}{(r^2 - a^2)^2} + \frac{b^2 y^2}{(r^2 - b^2)^2} + \frac{c^2 z^2}{(r^2 - c^2)^2} = \frac{p^2}{r^2 - p^2},$$

r being the radius vector of the wave surface, and p the perpendicular; in short, the process is substantially the same as the method of Archibald Smith.

The solution of the following problem illustrates the method of finding envelopes, some account of which has been attempted in this Paper.

The cone $x^2 \cot^2\alpha + y^2 \cot^2\beta - z^2 = 0$ intersects the sphere $x^2 + y^2 + z^2 = a^2$ in a sphero-conic. Show that the equation of the tubular surface, which is the envelope of a sphere of constant radius k, whose centre moves along the sphero-conic, is had by equating to zero the discriminant of the following cubic in λ:—

$$\frac{4a^2 x^2 \sin^2\alpha}{P^2 + 4\lambda a^2 \cos^2\alpha} + \frac{4a^2 y^2 \sin^2\beta}{P^2 + 4\lambda a^2 \cos^2\beta} - \frac{z^2}{\lambda} - 1 = 0,$$

where

$$P \equiv x^2 + y^2 + z^2 + a^2 - k^2.$$

[See Unsolved Questions, "Educational Times," Reprint, No. 5447, vol. 55, page 136.] I leave it as an exercise to the reader.

I ought to add that equation (9) is due to the late Rev. W. Roberts, M.A., sometime Fellow of Trinity College, Dublin, but responsibility for the solution above given rests on myself.

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[Read February 17, 1897.]

I.—Introduction.

Slieve Gallion forms a conspicuous mass some nine miles west of the north-west arm of Lough Neagh, and is not to be confused with its rival, Slieve Gullion, which stands in the county of Armagh. These two crests are, however, visible from one another on a clear day, across the intervening forty miles of lowland.

Slieve Gullion, as is fully admitted, represents the remains of a volcano contemporaneous with the intrusion of the granite of the Mournes; and one of the objects of the present paper will be to prove that Slieve Gallion also is formed to a large extent of volcanic material. The occurrence of metamorphosed sediments in the neighbourhood has, however, complicated the question; and all the igneous rocks of the area, with the exception of the Cainozoic basalt, have at one time or other been claimed as of metamorphic origin. To this day, the difficult group of the diabases has been regarded as derived by crystalline changes from the local Ordovician strata,* despite the careful petrographic descriptions in the Memoirs of the Geological Survey. Messrs. Egan and Nolan, the official surveyors, seem to have seen so thoroughly what the district had to show, that it has been a pleasure to follow them, almost yard by yard, across the mountain; but the fifteen years that have elapsed since their work was carried on may have enabled us to form more precise conclusions as to the relations of the various masses.

Slieve Gallion and its spurs cover some sixteen square miles, and it will thus be necessary to use local names for several of its features. In this matter the six-inch Survey of Londonderry and Tyrone has proved of service; but a few points still require designation, for purposes of ready reference. I have thus named the great hollows that break the south-east face of the mountain after the townlands that spread, in each case, down their south-west slopes; while the summit of the one main track across the *massif*, leading to the valley of the White Water, has been styled "the White Water Pass."

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* Geol. Survey of Ireland, Memoir to sheet 27 (1881), p. 11; and to sheet 26 (1884), p. 12.

The accompanying sketch (Pl. xiii.) will serve to show the general character of the range. An old writer has spoken of the Slieve Gallion "mountains," a fact which may account for the same name being given to both the principal summits. The one styled here "Slieve Gallion North" is 1623 feet above the sea, and is the "Slieve Gallion Carn" of Survey Memoirs. The southern summit reaches 1735 feet; and the intervening moorland, covered for the most part with deep bog, does not sink lower than 1450 feet at the *col* above the White Water.

Between this passage and the dome of Drummuck lies the most picturesque and broken portion of the range, the rocks cropping out in terraces and bosses, with the steep scarp of basalt and chalk rising as a background in the north. Elsewhere, rock-exposures are comparatively few; and even the streams that have carved out deep hollows have at one time been choked with *débris*, through which they are now cutting little cañons. The red stainings of iron-ore that permeate these granite taluses render the ravines conspicuous at a distance; and they seem early to have attracted the attention of the peasantry. The first engineering operations on Slieve Gallion are attributed to a sister of Callann Mor,* who tried to remove the mass which stood between her and a friend in the county of Tyrone. But all the men who worked for her "got a sore in the fingers"; and it was said that "anyone that would attempt to cut away the mountain would take the same sore." The "Red Bank" is shown as the place of these prehistoric efforts; and it is in reality probable that iron-workings were attempted here in very early days.

While the south-eastern face of the range descends into a pleasant land of wooded slopes and close-set farms, due to the Carboniferous and Triassic strata round Moneymore, the view north-westward from the *col* is one of utter contrast. The region of undetermined schists stretches from Slieve Gallion in that direction into Donegal; and the wild masses of the Sperrin Mountains form a highland rarely traversed. Between their base and the ridge on which we stand, the moor is almost continuous; but here and there a lakelet lies gleaming among the little hills of gravel, which rise as strange cones above the broad curvings of the foot-hills.

The bold road which climbs so steeply from Desertmartin, and which runs along the north-west terrace of the mountain, descends again on the south by the glen of Lissan, after commanding a series of superb and desolate moorland-views. It has its counterpart on the sunnier side of the range in the road from Dirnan to Tintagh and Iniscarn; and the frequent and well made branches, by which the peat-carts go up and down, afford easy access to the mountain.

Such is Slieve Gallion—an isolated ridge, a kind of hog's-back, indented by four great combes on the south-east, and by one main valley, that of the White Water,

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* John O'Donovan, "Letters containing information relative to the Antiquities of the County of Londonderry, collected during the progress of the Ordnance Survey in 1834." MS., p. 225. R. I. Acad. Library.

on the opposite flank. The northern end is still capped by an outlier of almost horizontal basalt, preserving a thin layer of chalk, and repeating the features of the Antrim plateaux. Hence it is unlikely that the summits were ever peak-like or serrated, at any rate since the time that they formed part of the floor of the Cretaceous sea. The cirques at the head of the great combes have now become choked and grass-grown; and both flanks of the range are covered by huge fan-like taluses. The great days of Slieve Gallion, however, must have been when it rose as a promontory in the Carboniferous ocean, a buttress of the contorted district to the north and west. The Carboniferous sandstones that rest against the mountain are largely composed of its products of decay*; and denudation is now-a-days, as in the Wicklow mountains, restoring to us, on a somewhat reduced scale, the scenery of Palæozoic shores. At the north end of the mountain, the mantle of Carboniferous sandstone has not yet been stripped away, and the rocks are conspicuous by their stratification and their warm red-brown colour.†

Gerard Boate,‡ in 1755, referred to the possibility of mineral wealth in "the mountains Slew-galen"; and an iron-mine was then being worked in the Lissan valley. His suggestion that "rich gold mines do lye hidden" in Slieve Gallion seems still to exercise a fascination over the peasantry, who believe their highland, from Carncose to Oritor, to be capable of great mineral development. Nor are they discouraged by the failure of various attempts at iron-working,§ but regard all geologists who visit them as speculators in gold or coal.

G. V. Sampson's map,‖ which was issued by the Dublin Society in 1802, records the occurrence of granite on Slieve Gallion, and of basalt and "white lime" on the northern summit. His mineralogical and geological notes show characteristic powers of observation.

Jean François Berger¶ carefully examined the mountain in 1816, especially noting the granitic series and its variations.

Sir R. Griffith,** in 1829, showed an acquaintance with the problems of the district; and the changes made in successive editions of his famous Geological

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* Geol. Surv. Mem. sheet 27, p. 16, &c.

† The upper part of these sandstones, on the steep scarp of Slieve Gallion North, was regarded by Portlock as Triassic ("Report on Geol. of Londonderry," p. 114; also G. H. Kinahan, "Geology of Ireland," p. 141). Mr. Egan, however, with much probability, has referred them to the reddened Lower Carboniferous series (Geol. Survey Mem. sheet 27, p. 18).

‡ "A Natural History of Ireland," Pt. i., pp. 69 and 71.

§ See G. V. Sampson, "A Memoir explanatory of the Chart and Survey of the County of London-Derry, Ireland" (1814), p, 97. Also Geol. Surv. Mem. sheet 27, p. 42.

‖ "Statistical Survey of the County of Londonderry, drawn up for the Dublin Society."

¶ "On the Geological Features of the North-eastern Counties of Ireland." Trans. Geol. Soc. London, vol. iii., p. 144, &c.

** "Geological and Mining Surveys of the Coal Districts of the Counties of Tyrone and Antrim," p. 1.

Map of Ireland* mark his growing appreciation of the complex character of the mass.

O'Donovan,† in 1834, found the names Slieve (or Sliabh) Gallan, Callann, and Gallion, all in use, and states that the range was probably named from the giant Callann Mor. This hero is said, by-the-by, to be buried in Carnanbane, on the moorland-slope above Lough Fea.

Whitley Stokes,‡ in 1838, has an odd little reference to "globules of quartz" occurring in the "limestone of Slieve Gallion"; and his comparison of these with the pebbles of the mulatto-stone of other areas is aptly confirmed by the work of Mr. Egan,§ who found what is practically the "Hibernian Greensand" *in situ* on Slieve Gallion North.

Portlock's "Report on the Geology of the County of Londonderry and of parts of Tyrone and Fermanagh," appeared in 1843, and contains a number of new observations on Slieve Gallion. The theoretical deductions must now-a-days, however, be received with considerable caution.

Prof. J. B. Jukes's geological map of Ireland (1870) shows all the rocks of Slieve Gallion as either granite or of metamorphic origin; but Prof. Hull was enabled, in his revision of the map in 1879, to insert a larger amount of detail. Mr. Nolan's results were published in the same year,‖ and include, as we shall see, some very remarkable advances towards an understanding of the district. The Geological Survey of Ireland issued sheet 27, including the main mass of Slieve Gallion, in 1880, and sheet 26, containing the wild moorlands to the west, in 1882. The corresponding memoirs, by Messrs. F. W. Egan and Joseph Nolan respectively, are dated 1881 and 1884.

In 1889, the Longitudinal Section, sheet 27, including a traverse of Slieve Gallion, completed the work of the Survey. E. T. Hardman¶ had already, in 1876, published a section across the mountain, which differs so far from that of Portlock as to suggest independent observation. Both this and the map accompanying it may, however, be set aside, now that we have the more detailed results provided by Mr. Egan.

The valuable "Guide" of Messrs. McHenry and Watts** naturally contains

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[*] Portlock, "Report on Geol. of Londonderry," pp. 77 and 81. I have been unable to trace the edition of 1838 referred to by Portlock, and many copies of the map of 1839 contain the changes attributed by Portlock to that of 1842. These may, however, have been subsequently coloured on sheets printed off in 1839.

[†] *Op. cit.*, MS., p. 225.

[‡] "On Globular Formations," Journ. Geol. Soc. Dublin, vol. i., p. 18.

[§] Mem. sheet 27, p. 29.

[‖] "On the Metamorphic and Intrusive Rocks of Tyrone." Geol. Mag., 1879, p. 154.

[¶] "On the Age and mode of Formation of Lough Neagh, Ireland." Journ. R. Geol. Soc. Ireland, vol. iv., plates xi. and xii.

[**] "Guide to the Collections of Rocks and Fossils, Geol. Surv. of Ireland" (1895), p. 73.

fresh information as to the petrography of the area; but the basic series of Slieve Gallion itself remains practically unnoticed. Despite previous investigations, the mountain is sufficiently remote from the routes of ordinary travellers to offer an attractive field; and I hope that my own observations may at least indicate its interest.

The occurrence of "andesitic volcanic tuff" among the pyroxenic rocks of Slieve Gallion, and of highly silicated and basic igneous rocks at Oritor, were recorded by myself in the reports of the Dublin Microscopical Club during 1896.* I now propose to describe the various masses referred to, in their field-relations and in their bearing one upon another.

II.—The Andesite and Diorite Series.

The series thus designated includes the whole of the "Pyroxenic Rocks" dealt with in the Memoir to sheet 27 of the Geological Survey. They are mostly chloritic, forming, in fact, typical diabases,† using that term in its wide and practical significance; but their resemblance to the similar grey-green altered rocks of other areas leaves no doubt as to their igneous origin. Respect for the views of Portlock, who regarded them as metamorphic products in 1843, may have prompted the somewhat remarkable statements of the Survey Memoir,‡ published in 1881; but the work that had been done meanwhile in other areas of the British Isles, not to mention the investigation of numerous diabases and schalsteins on the Continent, had already shown how igneous rocks may come to resemble sediments or schists, and how certain characters may none the less remain, by which their true mode of origin may be traced.

In the system of colouring adopted in sheet 27, we are asked to regard these "pyroxenic rocks" as graduating into Ordovician sediments, and as produced by metamorphism from them. In sheet 26, which includes the west end of Slieve Gallion, they are represented in precisely the same relation to Ordovician beds ("β 1 to 2"); but in the index to that sheet, as in the accompanying memoir,§ they are said to be "probably of pre-Cambrian or Upper Laurentian age." They are thus swept into the series that forms the moorland west of Cookstown; but part, at any rate, of the supposed Ordovician strata of this sheet becomes drawn back also, by the same stroke, into the Archæan era, in virtue of its relations to

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* *Irish Naturalist*, vol. v., pp. 245 and 312. The remarks in the second reference apply to the neighbourhood of Oritor better than to Oritor Quarry.

† J. F. L. Hausmann, "Ueber die Bildung des Harzgebirges" (1842). Zirkel, "Lehrbuch der Petrographie," 2nd edit., Bd. ii. (1894), p. 650.

‡ Mem. sheet 27, p. 11.

§ Mem. sheet 26, pp. 12, 15, and 16.

the "pyroxenic rocks." This point is not faced in the memoir; and we should have been clearer if the authors responsible for sheets 26 and 27 had declined to fit the northern parts of their maps together, or had definitely placed the "pyroxenic rocks" on two horizons.

In the longitudinal section, sheet 27, published in 1889, "metamorphic rocks" and "hornblendic rocks of several varieties" occupy the position of the diabase series, and they are shown graduating into schists on Fir Mountain to the west, as no doubt they actually do.*

J. F. Berger,† in 1816, observed "several unconnected masses of greenstone" upon Tintagh Mountain, described their veins of calcite, barytes, and red ironstone, and clearly distinguished them from the "flat stratified trap" above the Chalk. Personally, I think that we have good grounds for linking even the coarse pyroxenic rocks of Oritor with the andesitic series of Slieve Gallion, as Mr. Nolan actually did in 1884. But the question of their age is a large matter, which cannot be entered upon here. I propose first to describe some of these "pyroxenic rocks" and their mode of occurrence in the field.

In the first place, with the exception of certain chert bands, I can find nothing in the supposed Ordovician series of Slieve Gallion to suggest a normal sediment, though such may exist in sections, now concealed, in the extreme east of the area.‡ Wherever I can find the rock exposed, it seems at least as "pyroxenic" a type as in the regions coloured darkly on the map; and at Tirgan Rock and Carncose Rock, which are included in the sedimentary area, the bosses seem to me entirely igneous.

But a gradation from the compact igneous type to a bedded condition undoubtedly occurs; and it is this that has probably led to a misapprehension of the diabase series.§ Where the townlands of Carncose and Tirgan abut upon the mountain, a number of rocky terraces and knobs break the ascent. On the lowest of these, Drummuck, there are grey flinty rocks, sometimes dark, sometimes pale, with an almost shaly structure, and a distinct dip towards the north. The summit of Drummuck is formed of vesicular andesite, and the south end shows an aphanite, probably intrusive. In microscopic section, the bedded rock is seen to consist of granular plagioclastic felspars, heaped together, with some biotite and altered pyroxene. Epidote occurs, as it does in the whole diabase series. There are no obvious scoriaceous particles, such as might prove the deposit to be volcanic;

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* See also Mem. sheet 26, pp. 12 and 15; Portlock, "Geol. of Londonderry," p. 544; and McHenry and Watts, "Guide to the Rocks and Fossils, Geol. Surv. of Ireland," p. 73.

† "Geol. Features of the North-eastern Counties of Ireland," Trans. Geol. Soc. London, vol. iii., p. 149.

‡ Mem. sheet 27, p. 10; Glenview, for example.

§ Sir R. Griffith, in the edition of his Geol. Map of Ireland dated 1855, colours this series as "porphyritic slate in which the sedimentary lines are still traceable, passing into greenstone porphyry."

but the slide examined contains one fragment of devitrified perlitic glass. The association of these rudely stratified rocks with an obvious lava, and the character of their constituents, strongly suggest that they are volcanic ashes. The preponderance of felspar crystals may be due to the action of water on a more complex deposit, washing out the minute pumiceous fragments and leaving a crystalline volcanic sand. A similar phenomenon among the ashes of Cader Idris has already received this explanation.*

A series of andesites is displayed upon Craigmore, the highest layer showing ashy characters; and the andesites in Brackagh-Slieve-Gallion, to north and west, become schistose here and there, and may contain a good deal of interbedded ash. A section of the rock west of Craigmore, at a height of 1250 feet, shows amygdaloidal scoriæ embedded in a finer ground (Pl. xiv., fig. 1). Some of the fragments contain large augite crystals, and show the nature of the original andesitic lava. The section thus confirms the first impression made by the rock in the field. South of Craigmore, across the road from Drumcormick to the White Water Pass, lies the picturesque mass of Windy Castle. In the hollow between this and the next ascent towards the pass, the andesites are again associated with fragmental rocks, which reveal their structure on their weathered surfaces. These knobs of rock jut out upon the moorland that forms the east side of the Tintagh Hollow, and break the slope with a boldness rare upon Slieve Gallion. At 1330 feet we have a tuff, containing fragments of andesite 10 to 18 centimetres across; as in the previous case, the disrupted rock was a scoriaceous lava, now amygdaloidal, containing large porphyritic augites. Lower down the slope, the tuff becomes finer in grain, and in section the augite crystals are seen to lie separated in it, with scoriaceous fragments of various kinds of andesite, some rich in pyroxene, others rich in felspar. The lavas have become so far broken up as to set free the porphyritic augites; and the rock reminds one, on a smaller scale, of the tuffs of Rhobell-y-Big,† an area with which Windy Castle may be compared in very many of its details.

These rocks, especially in microscopic section, are not likely to be confused with the true breccias produced by earth-movement, which occur at other places in the andesitic series of Slieve Gallion. They form the nearest approach to sedimentary rocks that I can trace in the "Lower Silurian" areas; although, among the "pyroxenic rocks" on the east of the summit of Tintagh Mountain, dark bedded rocks occur, which may represent slightly ashy muds rather than muddy volcanic ashes. We must, indeed, cross the pass, and descend the White Water for some two and a half miles, before we find anything like a continuous stratified

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* Cole and Jennings, "The Northern Slopes of Cader Idris," Quart. Journ. Geol. Soc. London., vol. xlv. (1889), p. 427.

† G. Cole, "The Rocks of the Volcano of Rhobell-fawr," Geol. Mag., 1893, p. 342.

series. Even then, among the schistose layers by the stream, on the southern side of Straw Mountain, we may possibly mistake foliation-planes for original bedding. A section prepared from one of these greenish rocks shows that considerable alteration has set in; secondary quartz fills all the cracks and cavities, and the main mass is largely chloritised. The structural planes were probably impressed upon the rock by shearing; and in its original condition it may easily have been an andesitic ash. The dip of the structure-planes is north; and this is repeated in the bluffs on the White Water, a mile above the bridge, on the ascent towards Slieve Gallion. All these greyish, greenish, and pinkish rocks strongly suggest volcanic ashes, and I believe that true bedding occurs among them. At the same time, a compact diabase, associated with them on the upper White Water, shows in section such evidence of crushing, with consequent production of structural planes, that I am willing to suspend judgment until the series can be traced farther north. The fine-grained schists of the Sperrin Mountains, so far as I have seen them in the field, differ widely from the White Water series; and their micaceous foliation-planes place them as distinctly metamorphic.

I attach considerable importance to the tuffs of the Windy Castle area, especially in connection with the vesicular andesites that are associated with them. It seems difficult to believe that the latter, so carefully noted by Mr. Egan,* should have raised no suspicion of the volcanic origin of the series.†

The andesites themselves, and their more crystalline representatives, the aphanites, are first met with at a height of 500 feet in the east of Brackagh-Slieve-Gallion, at 575 feet in the adjacent Tirgan Rock, and at 1075 feet on the south side of Windy Castle. In the last two cases, they are in contact with the underlying granite, which rises round Slieve Gallion South to 1600 feet. Hence the andesitic series may be either a comparatively thin one, bent down on the flanks of the mountain and forming a mere arch above the granite core; or it may be one of variable thickness, eaten away to a greater or less extent by the invading granite on its lower side. The frequency with which signs of contact-alteration are seen in the field, as we ascend for 1000 feet over continuous andesitic rocks, indicates that we are nowhere far distant from the granite; and I doubt if the series, as it remains to us, is at any point thicker than 200 feet (Pl. xiii).

The rocks in contact with the granite are by no means of uniform character; but they have generally become flinty, and some of the ash-beds at Drummuck and Craigmore are almost porcellanous, and can no longer be scratched with a knife. In this condition they weather almost as white as the altered rhyolitic ashes of Cader Idris.

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* Mem. sheet 27, p. 12.

† Mr. Nolan also notices amygdaloids among the schistose rocks of Slieve Gallion ("Rocks of Tyrone," Geol. Mag., 1879, p. 156). See also Portlock, "Geol. of Londonderry," pp. 545 and 542.

The andesites are usually compact lithoidal types, grey-green to deep grey in colour, and sometimes fissile and difficult to distinguish from sediments. Dark rocks, easily scratched with a knife, and resembling coarse argillaceous beds, occur thus, in intimate association with the diabases, on the east slope of Tintagh Hollow, on the eastern part of the crest of Tintagh Mountain, and on the southern edge of the plateau of Slieve Gallion South. Exposures in the higher moorland are too scattered to allow of the mapping of these rocks in detail; but I believe that they are merely modifications of the much altered lithoidal andesites, and their "bedding" is certainly in some cases due to subsequent earth-movement and brecciation.

At Tirgan rock, the dark lava into which the granite has intruded is an andesite rich in small porphyritic crystals of augite. It has suffered from admixture with the quartzose intrusive mass. A type more rich in felspar is seen in Brackagh-Slieve-Gallion, crushed and brecciated, in the neighbourhood of the fault which carries down the Carboniferous sandstones to the north. Above Windy Castle, again, we have a glassy representative of the basaltic andesites—a delicately spherulitic rock, with plagioclase microlites imperfectly developed in it, their forked ends recalling the similar crystals so prevalent in variolites and modern tachylytes. The specific gravity of this rock, in its present somewhat devitrified condition, is 2·99. I have elsewhere described altered tachylytes from the coast of Co. Down with specific gravities ranging from 2·86 to 2·93.

Another andesite, half a mile away, in a boss rising above the highest farm of Tintagh Hollow, shows in section a ground of green palagonite, and colourless microgranular material, with perlitic structure; the small curved contraction-cracks are now darkened by the development along them of closely set granules of epidote*; and dolomite, quartz, and white zeolites have arisen in the groundmass and in the fissures produced during alteration. The reference of the green groundmass to original tachylytic glass is borne out by the occurence of similar material in the hollows of the small porphyritic felspars. These hollows were certainly eaten out by the corrosive process of which we have evidence in almost every glassy lava.

In its lower part, this rock has been affected by the granite, and quartz has filled up its steam-vesicles. Its microscopic characters are so different from those of ordinary perlitic glasses, that I have even compared the section with some of the oolitic iron-ores of North Wales, the grains of which are green in transmitted light. The features of the mass, however, in the field, and the obviously igneous origin of its crystalline constituents, make me put forward the above explanation as the true one. In its uppermost part the rock is coarsely vesicular, and the striking amygdales are formed of pale pink calcite.

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* Compare F. Rutley, "On Perlitic Felsites from the Herefordshire Beacon, and on the origin of some Epidosites," Quart. Journ. Geol. Soc. Lond., vol. xliv. (1888), p. 740.

Vesicular andesites occur on Drummuck, Windy Castle, and Craigmore, having been rendered amygdaloidal, and then restored by weathering. Their association with the tuffs of this area, which are characteristically full of scoriaceous fragments, makes it safe to regard them as true lava-flows. On the north-western rocks of Windy Castle, a vesicular hornblende-andesite occurs, in place of the common pyroxenic varieties.

Vesicular structure is, indeed, fairly frequent among the andesites of Slieve Gallion. A striking example occurs on the very summit of Slieve Gallion South, as a layer dipping south among compacter masses. This rock is in part actually scoriaceous. The summit of Glenarudda Mountain consists of a delicate amygdaloid, the small vesicles being filled by quartz, epidote, and pyrite. A vesicular patch, again, is exposed among the more compact diabases in the bog above the hollow of Letteran.

On the higher levels of Slieve Gallion, west of the White Water Pass, hornblende-andesite is fairly common, forming the layer in contact with the granite. The hornblende is clearly an original constituent, and has not arisen as a contact-product. One example of this group of andesites occurs, with signs of brecciation, on the east of the crest of Tintagh Mountain; but the most typical exposures lie round and on Slieve Gallion South. The rock is non-scoriaceous and compact, and its groundmass resembles, in a remarkable degree, that of the nepheline-phonolites. In grain it is at the best only slightly coarser than the well-known Bohemian phonolites, and the dull grey-green colour forms an additional point of similarity. On weathering, the groundmass often becomes a pale pinkish white. Even under the microscope, the extremely altered character of the felspathic constituent, and the short habit of its crystals, suggest the presence of porphyritic nepheline; and it was with reluctance that I abandoned this idea, upon finding traces of repeated twinning in several of these decomposing crystals. The plagioclase, in fact, has been largely replaced by calcite, and the rock effervesces briskly, even when treated with cold acid. The hornblende, on the other hand, preserves its character fairly, though its green colour is likely to be due to incipient changes towards chlorite.

The compact hornblende-andesite of the summit of Slieve Gallion South, where there is a somewhat considerable rock-exposure, has a specific gravity of 2·82. In section, the glassy ground is represented by a colourless microgranular modification, in which the microlites and crystallites of the original glass have been preserved in all their delicacy.

In Mobuy, on the slope above Lough Fea, 530 feet lower than the last-named exposure, a similar but somewhat coarser andesite occurs, again in contact with the granite. Its specific gravity is 2·85, which is partly accounted for by the presence of epidote. The cumulites and other crystallitic groupings again show the former nature of the groundmass. A third example may be taken from the crest of the south-west wall of the Letteran Hollow, in Letteran itself; its specific gravity is only 2·76. The granite lies close below it; but no intermingling of material seems to have occurred. Moreover, the phonolitic aspect of the rock-mass is not confined to these hornblende-andesites. The flinty augite-andesite of Tirgan Rock, and a pinkish-grey mass on the bluffs along the upper White Water, were equally set down in the field as possible phonolites. In both these cases, the granite has sent off veins into the rock; and the compact character of the whole "pseudo-phonolitic" series seems due to contact-metamorphism acting on a groundmass of similar chemical composition, independently of the mineral constitution of the lava as a whole.

When passed in review, the hornblende-andesites of Slieve Gallion seem to have originally belonged to a type with trachytic structure, while the augite-andesites, which occur more commonly,* approach the basalts. But some among the latter are grey and very rich in small porphyritic felspars, being hemicrystalline representatives of the rocks styled "leucophyres" by Gümbel.† One of these paler andesites, from the head of the Letteran Hollow, gives, even under the microscope, no clue as to its original ferromagnesian constituent, irregular chloritic patches alone remaining. It has been thoroughly permeated by quartz, in insidious veins and streaks, and lies close above the interesting green chert-band which accompanies the diabases in that hollow. Veins of hæmatite also traverse the rock; but these various changes have not disguised the original highly felspathic nature of the rock. A more satisfactory example of these "andesites rich in felspar" occurs among the dark compact rocks of the eastern part of the crest of Tintagh Mountain. It is traversed by numerous eurite veins; but enough of its structure remains clear. One or two porphyritic crystals of augite appear, while plagioclase, in short stout prisms, is simply abundant. The groundmass was originally minutely vesicular; and some remelting seems to have gone on in contact with the invading veins.

The compact rock which has been already referred to, from the bluffs on the White Water, two-thirds of a mile from the pass, is now much brecciated, but was originally one of the highly felspathic andesites. Its ferromagnesian constituent has been lost in epidote and chlorite.

Enough has now been said to show that, from end to end of Slieve Gallion, the whole series of normal andesites is fairly represented.

There remain, however, certain rocks more rich in silica, which approach the rhyolites; but they occur very sparsely, and I believe that their quartzose character

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* Portlock regarded hornblende as the common constituent throughout Slieve Gallion, having correctly observed it at Windy Castle and elsewhere ("Geol. of Londonderry," pp. 210 and 538).

† See discussion by Rosenbusch, "Mikr. Phys. der massigen Gesteine" (1887), p. 200.

is due to intermingling with the granite. One of them, a grey flinty-looking rock, from the Letteran Hollow, in the neighbourhood of the felspathic andesite above described, proves to have a hardness of only about four, which removes it from the ordinary devitrified rhyolites or rhyolitic andesites. Under the microscope, its extremely altered character is apparent; and veins of both calcite and dolomite traverse it. Relics of porphyritic crystals of biotite can be recognised. The groundmass of quartz and felspar, lying between decomposed crystals of plagioclase, is in great part minutely micropegmatitic, and in part merely microgranular. It is difficult to say whether this rock represents a phase of the biotite-granite that lies below it, or of the older andesitic series that stretches above it to the plateaux of Slieve Gallion.

Holocrystalline representatives of the andesites, *i.e.* true aphanites or dolerites, naturally occur in association with the lavas; but none of these appear to have cooled at any considerable depth. With one exception, we have to go to Lough Fea and Lissan before we meet with anything so coarse as a diorite or a gabbro.

I have noted aphanite—using the term to cover both amphibole-plagioclase and pyroxene-plagioclase rocks—at Tirgan Rock, in a field to the north of the more conspicuous rocky bosses; at the south end of Drummuck; on the crest of Tintagh Mountain; at several points above the combe of the Derryganard Hollow; and in the little cliffs between the bog of Glenarudda Mountain and the gravel hills of Crockandun. It also occurs, associated with true hornblende-diorite, on an interesting boss in Letteran, and in Tatnagilta, south-west of Lissan.

A typical example of these holocrystalline rocks, closely allied to the surrounding compacter andesites, is that from the north-west side of Tintagh Mountain. It is green-grey, speckled with yellow dots of epidote; and patches of pyrite emphasise its altered character. In section, it is a typical diabase, an altered dolerite, consisting of rod-shaped crystals of plagioclase, brown augite ophitically surrounding them, and abundant magnetite. Chlorite has developed along the cracks of the augite, and needles of green secondary amphibole spread from the crystals, penetrating the adjoining felspars. These needles jut out parallel to one another, forming delicate palisades, the components of which are often similarly oriented at opposite ends of the originating crystal of augite. They thus differ from the ordinary fibrous zones of the "flasergabbros," and may occur at two terminal regions of a crystal and not upon its other sides, suggesting a polar arrangement.

In the section examined, two lumps of foreign material occur, no doubt of sedimentary origin, and picked up by the intrusive dolerite; the contact-zone formed round them is marked by the small size of the augite and felspar crystals, which developed rapidly against the derived fragments. Plates of biotite, stretching inwards from the surface, have arisen in the fragments themselves. The best preserved inclusion is clearly formed of granular calcite; and the conversion of this particle of ancient limestone into a biotite-calciphyre reminds one in miniature of the well-known blocks of Monte Somma.

The felspar crystals of this dolerite are frequently bent by earth-pressures; and other doleritic rocks occur on Slieve Gallion in which a brecciated structure has been produced, almost obliterating their original well crystallised character.

The first mineral to disappear in such cases is the pyroxene; and green streaks and patches of chlorite fill the interspaces between partially rounded felspars. It is possible that actual fusion has begun in such instances, and that the invasion of the granite is responsible for much that looks like brecciation. The augite would form a fluid ground in which the undestroyed crystals of lime-felspar and magnetite would be borne along*; the mass would thus yield very readily to deformation; and, on its final consolidation, disturbed and rounded felspars would be found lying in a basic glass. The alteration of this glass would give the green interstitial patches that we see to-day. A rock to which the foregoing description applies occurs north-west of Glenarudda Mountain, and is at the most fifty feet above the surface of the granite. The diabases immediately to the south-west actually lie at a lower level than the granite bosses of Glenarudda, and are simply seamed with eurite viens.

Quartz occurs in these altered dolerites, but in trifling amount, and clearly as a secondary product. We have now to consider a more difficult case, that of the aphanite of the Letteran Hollow, in which quartz is an important constituent of the groundmass.

From the flinty character of the contact-zone, from the remarkable degree of penetration of the diabase series by veins of eurite, and especially from the abundant granite veins in the coarse diorites to the west, we are led in the field to expect an actual intermingling of the two types of material, the one of highly siliceous, and the other of basic composition. Portlock† clearly observed something of this kind, although he regarded the granitic veins as produced by the "progressive action" of metamorphism in the "hornblendic rocks," and noted red felspars as developed by similar metamorphism in these masses. Mr. Egan‡ also speaks of a passage from the one rock-type to the other, and is supported by Mr. Nolan,§ both in his earlier and later memoirs.

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* On this selective melting of the constituents, compare Bäckström, "Uber fremde Gesteinseinschlüsse in einigen skandinavischen Diabasen," Bihang till kongl. svenska Vetenskaps-Akademiens Handl., Bt. 16, Afd. ii., p. 10; G. Cole, "On derived crystals, &c.," Trans. Roy. Dubl. Soc., vol. v. (1894), p. 246; and A. Harker, "The Carrock Fell Granophyre," Quart. Journ. Geol. Soc. Lond., vol. li. (1895), p. 136.

† "Geol. of Londonderry," p. 556; also p. 535.

‡ Mem. sheet 27, pp. 10, 12, and 15.

§ "Metamorphic and intrusive Rocks of Tyrone," Geol. Mag., 1879, p. 159, and Mem. sheet 26, pp. 10 and 11.

A great part of the intermingling observed in the field is associated with the presence of visible veins of granite or eurite, and will be dealt with in the next section of this paper. The aphanite and diorite of the south side of the Letteran Hollow present, however, features of greater delicacy.

These rocks form a conspicuous boss on the shoulder descending south-east from Slieve Gallion South, extending upwards for about 100 feet from a spot 1225 feet above the sea. They are completely surrounded by the granite or its euritic representatives, which reach the level of 1600 feet upon the slope above. The exposure measures only some 500 feet by 400 feet when set down upon the map, a small thing on the great side of the mountain (Pl. xiii.).

Hornblende-diorite is seen at the foot of the little cliff, just against the bend of the cart-track to the higher bog. The summit of the boss is, however, aphanitic; and the rock is here clearly related to the normal diabase series of Slieve Gallion.

There are pink felspars in the diorite, as well as in the surrounding granite; but microscopic examination shows that these must not be attributed to the introduction of granitic material. Sections prepared from different parts of the boss give, however, the following evidences of intermingling. First, quartz occurs in very varying quantity throughout the mass; it has moulded itself against the pre-existing altered felspars. Secondly, the quartz is in places associated with another felspar, as a micropegmatitic intergrowth, which forms a network of delicate veins. Thirdly, in the neighbourhood of the quartz, the altered prismatic felspar is commonly "restored" by an outer clearer zone, in which the repeated twinning of plagioclase is sometimes seen; its cracks have similarly been infilled with fresh felspathic material.

Fourthly, the ferromagnesian material is a green or brown-green hornblende, which is somewhat irregularly developed in contact with the prismatic felspars, and which retains pale cores here and there strongly suggestive of original pyroxene. On the other hand, in contact with the quartz, the hornblende is strikingly idiomorphic, and the best crystals are found almost surrounded by quartz (Pl. xiv., fig. 4).

The conclusion is that the original rock was a crystalline representative of the andesitic series which lies on the higher levels of the mountain, and consisted of pyroxene and plagioclastic felspar. The latter is too much decomposed for specific determination; the former has passed into green hornblende. The magma of the invading granite became intimately injected through the mass, and some of its chemical constituents were withdrawn to form fresh zones and infillings to the old felspars. The secondary hornblende of the diorite received new life; it was doubtless strengthened by similar material from the granite, and crystallised out boldly towards the intrusive veins. Finally, quartz, and occasionally micropegmatitic material, separated out in the remaining spaces, and bound the rock together. A quartz-diorite thus results, from the union of a much-decomposed gabbro with a fresh and active magma, richly endowed with silica.

The specific gravity of this rock is 2·76. A diorite from the south of Mobuy, which may, I think, fairly represent the original condition of the Letteran boss, has the far higher specific gravity of 2·95; while the diallage-gabbro midway between Lissan and Oritor, which is almost certainly another member of the same series, gives 2·98. On the other hand, the grey eurite on the shoulder west of the quartz-diorite of Letteran has a specific gravity of 2·66. These figures are certainly suggestive of the amount of new material which was received by the diorite of Letteran from the invading highly siliceous magma.

Although, as we have said, the occurrence of pink felspars in a rock of the diabase series is not sufficient to prove transference of material from the granite, yet it is easy to see in the field, on the west side of the Letteran boss, a "passage" from the one type of rock into the other.* Eurites, with pink crystals of true orthoclase, occur here, graduating naturally into granite; and the quartz-diorite provides a genuine passage-rock between these and the basic series of the district.

The microscopic characters of the quartz-diorite, and the deductions that seem to follow from them, agree with those given by Prof. Sollas† in his remarkable paper on "the Relation of the Granite to the Gabbro of Barnavave, Carlingford." Uralitic hornblende replaces the pyroxene of the Carlingford gabbro at its contact with granite veins: but, when occurring as derived crystals in the granite, the "diallage directly passes into a sage green hornblende." In other cases, biotite has arisen as the paramorphic product. The derived crystals of bytownite, which is the prevailing plagioclastic felspar in the Carlingford rock, have been injected with orthoclase, or with orthoclase and quartz, and, although dusty and corroded, have been restored in some cases with an external zone of orthoclase.

Similar zonal additions to derived crystals of plagioclase seem to have occurred at the junction of granite and gabbro on Carrock Fell.‡ Mr. Harker§ has also shown that hornblende, presenting good crystal-outlines, has "crystallized out from the modified granophyre-magma" at a similar junction in Skye, and also on Carrock Fell and in St. Kilda.‖ These facts, then, still further support the explanation given above of the idiomorphic character of the Letteran hornblende when in contact with the intrusive magma.

Moreover, a boulder from the west slope of Glenarudda Mountain gives evidence

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* See Mem. sheet 27, p. 12.

† Trans. R. Irish Acad., vol. xxx. (1894), pp. 494 and 495. Also *Nature*, vol. xlviii. (1893), p. 109.

‡ A. Harker, "The Carrock Fell Granophyre," Quart. Journ. Geol. Soc. Lond., vol. li. (1895), p. 137.

§ "On certain Granophyres, modified by the incorporation of Gabbro-fragments, in Strath (Skye)," *ibid.*, vol. lii. (1896), pp. 324 and 325.

‖ Note in paper by Sir A. Geikie, "Tertiary Basalt-plateaux of North-western Europe," *ibid.*, vol. lii., p. 393.

of a precisely similar character. In this case, the presence of an intrusive micropegmatite is clearly visible in the mass, the whole rock being cut up into hornblendic patches two or three centimetres across, divided by much whiter veins. This rock probably comes, like so many erratics on Slieve Gallion, from the region immediately to the south-west.

In section, the original gabbro, with clouded felspars interlocked with uralitic hornblende, is seen forming the darker areas; while the veins consist of a somewhat coarse intergrowth of quartz and a dusky and unrecognisable felspar. Biotite occurs, however, in these veins, and strongly suggests that they are offshoots of the biotite-granite of Slieve Gallion. The green hornblende that abuts on or is included in these veins has a well marked idiomorphic character, and has crystallised out under their influence, or after complete fusion in them (Pl. xiv., fig. 3).

The last aphanite that I need mention lies in the small townland of Tatnagilta, on the road from Lough Fea to Cookstown, a third of a mile north-west of Unagh School; the rock here passes into diorite. In section it is seen to contain much magnetite, and the green hornblende is largely chloritised. Doubtless the rock was formerly pyroxenic; and its structure is that of a typical dolerite. Veins of calcite, and also of epidote, traverse it, and there is some secondary quartz. The rock is important, as a link between the diabase series of Slieve Gallion and the gabbros and diorites of the Oritor area.

Still better evidence is given as to a connection between the two series in the exposures on the steep south-west flank of Glenarudda Mountain, or "Mobuy Top." Although the granite separates, in a band half a mile wide, the hornblende-andesites on the level of the highest farms from the handsome diorites in the angle of the roads below, yet some parts of the bosses formed by the latter have a structure essentially intermediate between the lavas and the diorites. Dark-green mica occurs, however, in the diorite of Mobuy, in addition to the hornblende; and I have not been able to determine if it is derived from commingling with the granite.

The compact diabases (originally andesites) of the summit of Glenarudda Mountain have their counterparts, again, in the somewhat schistose series in contact with the granite further south. This series comes in, for example, at the bridge half a mile north of Crockanney, 1000 feet below the summit; and the diabase of Tatnagilta, and other compact forms, serve to continue it into the moorland west of Cookstown.*

On the north-west side of Slieve Gallion, the only diorite that I have met with is a very decomposed mass, with reddened felspars, on the right bank of the White Water, among the ashy-looking rocks 500 feet below a conspicuous little waterfall. Owing to the proximity of eurite veins, I suspect that this rock, if a

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* Compare F. W. Egan, Mem. sheet 27, p. 1.

fresh specimen could be obtained, would repeat some of the characters of that of Letteran. In that case, its idiomorphic hornblendes would be seen to be due to the action of the invading magma upon one of the more crystalline members of the local diabase series.

Two dykes of dolerite, which I have not myself traced out, have been mapped, running north-west and south-east, one on each side of Slieve Moyle; they cut the granite, and are no doubt correctly assigned by Mr. Egan to the Cainozoic era.* The long flat capping of basalt, protecting the Cretaceous strata, and forming the summit of Slieve Gallion North, may thus have flowed from some local source. Even if not an outlier of the eastern plateaux, it is one of the most remarkable evidences of the denudation which the district has undergone.

III.—The Granite Series.

It must have been already recognised that the great part of the *massif* of Slieve Gallion consists of granite. A section drawn across it in almost any direction would at once show the importance of the intrusive mass, and the probability that the diabase series has been bent into an elongated dome, into which the granite found its way (Pl. xiii.). The division of the mass in the Survey Memoir into "Granite" and "Granitoid Porphyry or Elvanite" is not a very happy one, as all forms of the granite that are poor in mica seem to have been included under the latter designation,† even if the rock is "as largely crystalline as the granite." Moreover, the area coloured as elvanite on the map covers some exposures of highly typical biotite-granite, such as that immediately east of Tintagh post-office.

There is, however, a distinction in the field between the true granite and the "quartz-porphyry" or eurite type, the latter having a characteristic compact groundmass, which seems to have been formerly taken for continuously crystallised felspar. The eurites come in exactly where one would expect to find them, near the contact with other rocks in the top of the great granite dome.

The granite has been carefully described, in successive Survey publications, as consisting typically of quartz, pink orthoclase felspar, and a greenish mica. A second felspar, regarded as oligoclase, has been noticed.‡ South of Glenarudda Mountain, the rock becomes hornblendic, and forms the "syenite" of the Survey Memoirs. In the area separately coloured as syenite (*i.e.* hornblende-granite),§ there is a good deal of the ordinary biotite-granite. The hornblendic type is, however, well seen in the bosses immediately south-west of Ballybriest Bridge.

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[*] Mem. sheet 27, p. 33. Also J. Nolan, Mem. sheet 26, p. 17.

[†] Mem. sheet 27, pp. 13 and 14.

[‡] Mem. sheet 26, p. 10.

[§] *Ibid.*, pp. 12 and 10.

The hornblende-granite of Ballybriest was long ago described, under the name "sienite," by J. F. Berger,* who appears, however, to have overlooked the more prevalent micaceous type. His "felspar-porphyry"† seems also unduly extended, though he doubtless appreciated the difference between the eurites and the coarsely developed granites.

Mr. Watts‡ has referred to the prominent rocks of the Slieve Gallion area as "coarse granites more or less foliated, and passing into quartz-diorites." Blue quartz, hornblende, and biotite, are noted as constituents.

The characteristic rock, as seen, for instance, on the south side of Carndaisy plantation, is a red granite of medium grain, with dark green chloritised biotite. The orthoclase is dulled, and the Carlsbad twinning is rarely recognisable in the mass. Pyrite occurs, and occasional inclusions of the diabasic rocks are recognisable. These have been noticed on the craggy slope of Mobuy, but not exceeding 2 cm. in length.

A second felspar is present, as in most granites, but rarely shows its repeated twinning, even under the microscope. This considerable alteration of the felspars makes it difficult to trace them in the contact-rocks where intermingling has gone on; and even their specific determination is impossible.

As recorded by previous observers, hornblende becomes a constituent in the south-west of the area; and there is little wonder that some of the fine-grained forms of the granite have been regarded as passage-rocks into the schistose diabases and andesites.

Between Anney's Well (on the road from Lough Fea) and Ballybriest Bridge, the granite exhibits remarkable variations in grain. It is perfectly possible, at any rate, that the dark fine-grained type, at the same time rich in quartz and in hornblende and black biotite, results from amalgamation with the basic material close at hand. Half a mile to the north-east are the abrupt bosses of diorite already referred to, in the angle of two roads from Glenarudda Mountain; and into these the granite has sent numerous veins. How much of this diorite has been actually lost by intimate penetration and diffusion, it is now impossible to say; but the hornblende-granite, occurring at such a point, with diorite again to west of it, seems logically to carry out what has already been observed in Letteran.§

In section, the granite of Ballybriest Bridge shows that the quartz and most of the felspar crystallised out simultaneously, producing a rough pegmatitic structure. The idiomorphic felspar that occurs can often be recognised as plagioclastic, and

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* "Geological Features of N. E. Ireland," Trans. Geol. Soc. Lond. vol. iii., p. 145.

† *Ibid.*, p. 144.

‡ M'Henry and Watts, *op. cit.*, p. 73.

§ Compare the important work of M. Michel Lévy, "Compte-rendu du 17 septembre," Bull. Soc. geol. de France, 3me sér., t. xviii. (1890), pp. 915 and 916; and Ch. Barrois, on similar occurrences in Brittany, *ibid.*, pp. 917 and 920.

arose prior to the pegmatite. The position of the abundant green biotite is hard to understand, for it wraps round, and is limited by, the felspars of both kinds, and has thus developed interstitially. It includes apatite, as usual, but also crystals of felspar which have already included apatite. Sphene has developed early, and, when it is included in the biotite, the long axes of its lozenge-shaped sections lie parallel to the direction of the cleavage. The order of consolidation of the minerals seems to have been apatite, magnetite, sphene, plagioclase, orthoclase (possibly microcline), and quartz, and lastly biotite and a little hornblende. Epidote forms secondary veins.

The opposite extreme of the rock is seen in the fine-grained granite, almost an aplite, forming the rocky walls of Carndaisy Glen. Here precisely the same relations occur between the green biotite and the micropegmatite. The latter is of a poor quality, the quartz not being optically continuous over any appreciable area; but the interlocking of quartz and felspar is clearly marked. The felspar is much altered, minute muscovite having developed throughout it, as occurs in so many other exposures on Slieve Gallion; but indications of the twinning of microcline still remain. Magnetite and biotite are present, but in much smaller proportions than at Ballybriest; the biotite seems to have been forced to take up such positions as it could find when the "eutectic" crystallisation of the quartz and felspar took place. But the separation of all the three minerals was almost simultaneous, and intergrowths even of quartz and biotite occur.

The specific gravity of this aplitic granite is only 2·61; the biotite-granite at the bridge north of Crockanney gives 2·68; and the fine-grained hornblende-biotite-granite of Ballybriest Bridge, which possibly contains diffused material from the gabbro series, gives 2·76. The pink felspar, determined in a diffusion-column of methylene iodide, yields the following readings:—

S. of Carndaisy plantation, three specimens; sp. G. = 2·59, 2·64, 2·65.
S. of the diorite bosses in Mobuy, several specimens; sp. G. = 2·69.
Ballybriest Bridge, in the ordinary type of the granite, two specimens; sp. G. = 2·70.

Some of these variations may be accounted for by the difficulty of avoiding intergrowths of quartz; but, as far as possible, clean cleavage-fragments were used. The figures from Mobuy and Ballybriest clearly represent alterations in the felspar, and are due, as Prof. Sollas suggested to me, to the abundant development of muscovite.* The range of specific gravity shows how impossible it would be to track out these felspars, by experiments in the diffusion-column, in cases where intermingling of the granite and the gabbro have occurred.

Before leaving these coarser rocks of the granite series, it should be pointed

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* See also Hintze, "Handbuch der Mineralogie," Bd. ii. (1897), p. 1361.

out that they form some of the more broken scenery of the mountain, particularly in the craggy and picturesque descent from Glenarudda Mountain to Ballybriest.

The eurites of Slieve Gallion occur frequently in the form of veins, often tinged with epidote, but usually pink, traversing the basic lavas. Sometimes the intrusion has the character of a delicate network, as occurs in the farm-road west of Tirgan Rock, and on the edges of many larger veins on Tintagh Mountain.*

Even the coarser veins at Tirgan Rock consist of a finely granular type, in which the quartz and felspar are barely separable with the lens. But micropegmatitic structure is determinable, and the rock is clearly a reproduction, on a smaller scale, of the fine-grained aplitic granites in Carndaisy Glen. A section of the adjacent augite-andesite shows signs of admixture, as stated in the second division of this paper; traces of quartziferous veins occur in it, and a certain amount of biotite, which has possibly arisen as a contact-product.

Passing up over the broken andesitic ledges of Craigmore, we come upon a broad area under the Chalk, where small boulders of eurite lie in a pale sand derived from them. An actual exposure of coarse red eurite, approaching granite, is seen in a digging on the south side of the road; and Mr. Egan has, with characteristic accuracy, carried the eurite (elvanite) on his map from this point over to the White Water Pass. A similar pavement of small boulders, consisting in this case of mixed granite and andesite, seems to point to a boss of these rocks within the region mapped as Cainozoic basalt. It occurs in the middle of the southern prolongation of the basaltic tableland, and possibly represents an old eminence which the Chalk itself did not overtop.

The eurite on which the chalk was deposited in Brackagh-Slieve-Gallion is a compact grey type, with quartz granules and a fair amount of porphyritic plagioclase, indicating a step towards the quartz-aphanites. But it is probably only an offshoot of the granite series, rich in soda. The section examined shows the characteristic green biotite; but the rock is injured by brecciation, like several of the andesites in the lower part of the same townland. In its present condition, this eurite has a specific gravity of 2·72, clearly representing the basic end of the granite series.

More typical grey and pink-brown eurites occur on the top of the granite of the White Water Pass, and in contact with the diabases of the overlying Tintagh plateau. They have been exposed in the cuttings along the upper part of the road from Tintagh post-office. The rock has a very compact and almost flinty ground, with granules of porphyritic quartz, and dull and inconspicuous idiomorphic felspars. This eurite is traceable to the north, until it becomes lost in the bog around the upper branches of the White Water.

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* This intrusive character was of course not overlooked by Mr. Egan (Mem. sheet 27, p. 13). See also Portlock, "Geol. of Londonderry," p. 542.

The fragments of eurite on the pass supply the red colouring to the taluses, the granite pebbles associated with them decomposing in far paler tones. But this is due rather to the development of iron-ores in fissures in the higher levels of the mountain, and the consequent staining of the eurite, than to any difference of constitution between the rocks themselves.

The granite at the highest farm in Tintagh makes an interesting junction with the vesicular andesites, as will be presently described, sending off veins of eurite into them. The whole contact-phenomena can be easily studied in these little protrusions between the farm-house and the road. On the east of Tintagh Mountain itself, eurite veins are common in the andesites, but have been extensively attacked by decomposition. In outward appearance they resemble the very fine-grained type, the so-called "compact felspar" of older authors; but they are disappointing in microscopic section, owing to the prevalence of epidote and calcite. In fact, they have become much more calcareous than the vesicular andesites which they traverse.

An almost continuous section in eurite, extending over half a mile, is seen in the ravine of the stream descending from Slieve Gallion South into the White Water. This is probably typical of much that is hidden by the boggy slopes on this side of the mountain. The eurite is here traceable, from a pinkish and greyish form at about 1500 feet above the sea, to red porphyritic forms at 1200 feet. In the middle of the section, hæmatitic gravel obscures the banks, and the eurite becomes much redder in its neighbourhood. I think we shall be right in regarding the grey and grey-brown types as representing the original condition of the eurite.

On the same general level, but against the main stream of the White Water, pink compact veins traverse the diabases. The specific gravity of these veins is 2·71.

An unexpected band of dark grey-eurite, with porphyritic quartz and colourless felspar, crosses the White Water north-west of the bridge on the Desertmartin road. Its relations to the schistose and probably ashy diabases are unseen, but it is no doubt a northerly protrusion of the great granite series of Slieve Gallion. Already, owing to signs of secondary flow, due to earth-pressures, it has assumed a metamorphic aspect; and it is easy to see how further metamorphism would convert it into a fine-grained gneiss, closely resembling, for example, those of Torr Head in the county of Antrim.

The finest exposures of eurite, in a little modified state, lie at 1250 feet on the shoulder of Letteran, between the Letteran and Derryganard Hollows. In the stream-cuts north-east of Slieve Moyle, the hæmatitic granite passes here and there towards eurite; but further east, between Tory's Hole and the boss of diorite, a somewhat coarse porphyritic eurite, grey and fresh-looking, appears in a series of small outcrops. A red form, which is clearly the same rock stained with iron oxide, is closely associated with it, and is exposed again higher up the slope. Ordinary red granite, much altered, occupies the head of the combes, with here and there a thin euritic zone where it abuts against the diabases of the plateau. It must be confessed that there seems nothing, in the arrangement of the rocks that have been spared to us by denudation, to explain the prevalence of eurite in the middle of the mountain-spur of Letteran.

The specific gravity of the grey eurite of Letteran is 2·66; and its microscopic characters also connect it with the main mass of the granite. Some of the constituents are glomero-porphyritic groups, in which biotite, quartz, and altered felspar are associated precisely as in the granite of Ballybriest. The quartz crystals preserve their outlines fairly, as in typical "quartz-porphyries"; but they have undergone some corrosion from the groundmass. Orthoclase is the most prevalent porphyritic felspar, and the green biotite is also well developed and idiomorphic, except in the glomero-porphyritic groups. The groundmass is micropegmatitic to microgranular, without globular structure, and resembles in miniature the granite of Carndaisy Glen.

Inclusions of green schistose material, doubtless derived from the diabase series, occur in the reddened form of this eurite 200 ft. higher up the slope; and a flinty rock, lying between the grey eurite and the boss of diorite, is possibly of mingled origin. Its specific gravity is as high as 2·78, and it contains a large amount of porphyritic plagioclase. These crystals, however, are idiomorphic, and the groundmass between them is a micropegmatite rich in quartz. There is rather more biotite, in streaks and irregular patches, than in the normal eurite; but nothing in the section is conclusive as to the mixed character of the mass. Possibly it represents the extreme of the granite series in approaching the quartz-aphanites, and may be compared with the brecciated rock under Slieve Gallion North.

A more remarkable rock, illustrating the difficulties of the contact-zone, occurs at the junction, already referred to, west of the highest farm of Tintagh Hollow. It has the character of a grey eurite in the mass, with dull opaque white felspars; but in section there is very little of the characteristic micropegmatitic groundmass. The coarser felspar, indeed, is in part associated with the quartz, as in the granite of Carndaisy Glen; but the groundmass round about such patches is supplied by a greenish fluidal material, which has no counterpart in the other eurites. In this ground, angular grains of quartz, and orthoclase and plagioclase felspars, are floated apart from one another; but it is often clear that adjacent grains belonged to one original crystal, and the structure thus resembles brecciation. The quartz has been corroded by the green material, which enters into it in tongues; and this rock, with its two types of groundmass, proves to be a singular product of intermingling. As at Glasdrumman Port,* an attacked and remelted andesite has succeeded in attacking its invader, and the granite or micropegmatitic eurite has become

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* G. Cole, "On derived Crystals, &c.," Trans. Roy. Dubl. Soc., vol. v. (1894), p. 244.

broken up and penetrated by a groundmass of basic glass. The specific gravity of this rock is 2·73, a figure close to that of the mingled quartz-diorite of Letteran.

Turning again to the extreme west of the mountain, we may note the delicate veins of pink eurite that penetrate the andesites in Mobuy, producing some of the most beautiful interminglings observable with the naked eye. The veins in the diorite bosses to the south are coarser and truly granitic; and both types occur, again, in the road-side quarries of Tatnagilta.

IV.—Relations of the Rocks of Slieve Gallion to those west of Cookstown.

As already pointed out, most authors have treated the "pyroxenic rocks" of the south-east of the county of Londonderry and the adjacent part of the county of Tyrone as belonging to the same series.* The schistose rocks between Lough Fea and Tatnagilta† form an apparent break upon the map, but are admittedly in close relations with the more crystalline masses on either hand. I have made one or two excursions into the moorland-parish of Kildress, in order to satisfy myself as to the similarity of the features presented there on the one hand, and in the *massif* of Slieve Gallion on the other. The whole area requires separate investigation; but the observations here given bear, I think, directly on the questions discussed in the present paper.

The quarries of the townland of Tatnagilta open up the problems of Kildress, and suggest that we shall encounter a basic series, ranging from gabbro to compact diabase, and penetrated by granite and eurite—in fact, an extension of the phenomena seen on the steep hillsides of Mobuy.‡ To the south-west, the roads at once enter what Portlock has styled§ "a singularly wild and rugged district, in fact, a mere plain of rocks." New roads have been cut through it since his time, and cultivation has spread around the feet of the rocky bosses; but the area still remains a strange one, an undulating land some 600 feet above the sea, with gravel hills and long weird eskers, contrasting with the abrupt domes of the gabbro.

On proceeding south to Oritor, we come at once on the typical landscapes of the district, and find far coarser igneous rocks than those of the summits of Slieve Gallion. A handsome dark diallage-gabbro, passing by uralitisation into hornblende-diorite, is undoubtedly the prevailing rock. Even in its freshest condition, it contains a fair amount of actinolitic hornblende; and the plagioclase is usually

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* Sir R. Griffith, "Geological Surveys of the Coal Districts of Tyrone and Antrim" p. 1; Portlock, "Geol. of Londonderry," pp. 530 and 538; Nolan, Mem. sheet 26, p. 12; &c.

† Mem. sheet 26, p. 15; Mem. sheet 27, p. 11.

‡ See the end of division II. of this paper.

§ "Geol. of Londonderry," p. 533.

much altered. But an ophitic character is discernible, despite the zones of interaction between the constituents. These zones sometimes consist of a colourless amphibole; and iron-ores are not at all prominent. Thus, whether pyroxenic or amphibolic, the rock stands well within the diorite group. The lustre of the schillerised pyroxenes has caused some of them to be referred to hypersthene by older authors; but the microscope shows that the mineral is not rhombic. The specific gravity of the gabbro in the north of Tullycall is 2·98.

In the mass, the diallage masks the felspar, and the latter mineral may be at some points almost absent. Mr. Watts* thus describes diallage-rock among the coarse gabbros of Athenree and Termonmaguirk. The basic rocks of the area have been generally referred to as "ophyte" by Mr. G. H. Kinahan.†

Granite veins, passing into eurite, traverse them, reminding us of the slope of Mobuy.‡ This granite is poor in ferromagnesian constituents, and is sometimes devoid of them, except for derived hornblendes from the basic series. A micro-granular pink-brown eurite, in the dolerite of the south-east of Feegarran, has a specific gravity of 2·61, identical with that of the fine-grained aplitic granite in Carndaisy Glen.

Occasionally veins of pure felspar occur, which are obviously extruded from the underlying granite, but which are not familiar to me in other areas. These are sometimes milk-white, sometimes pink, and the individual crystals may be 3 mm. across. A microscopic section across one of these veins, traversing ophitic hornblende-diorite (altered gabbro) one mile north of Oritor, shows the felspar composing it to be untwinned. The specific gravity of this pink felspar is 2·60. The white felspar of the veins in a diorite further west gives 2·59 to 2·64; in this case, the flame-reactions by Szabó's method indicate the species as a soda-orthoclase. We have, then, actual veins of orthoclase-rock as part of this "plutonic complex."

In the case last cited, the vein contains a little derived hornblende, and one or two crystals of sphene.

Immediately north of the mill at Oritor, under the gabbro-domes of Craigs, a fine quarry exposes a variety of igneous rocks. At the north end, a seemingly bedded series, dipping N.N.E., lies above a diorite, which is regarded as hypersthenite in the Survey Memoir; but the proximity of hornblende-schist, clearly derived from some basic rock by metamorphism, makes it likely that the appearance of bedding in any part of this quarry is superinduced. The soft grey talcose rock in which this feature is exhibited is probably itself a decomposed andesite.

The main rock of the quarry is a diorite, passing into an amphibolite in some places, and in others into a form with much dull pink felspar, the "syenite" of

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* McHenry and Watts, *op. cit.*, p. 73. Compare Portlock, *op. cit.*, pp. 519 and 549.

† "Economic Geology of Ireland," Journ. R. Geol. Soc. Ireland, vol. viii. (1887), p. 160.

‡ Compare Mem. sheet 26, p. 13.

Portlock.* A compact and almost black diabase occurs in the upper part of the quarry, penetrated by the felspathic diorite. In section, this rock is seen, as above hinted, to be in the condition of hornblende-schist.

The most startling feature in the quarry-face is the occurrence of a massive dyke of rhyolite, a pink-red compact rock, of an almost translucent "hornstone" type, cutting through the basic series at an angle of about 40° (Pl. xiv., figs. 2 & 5). Its specific gravity is 2·65, owing to secondary devitrification; but in microscopic section it shows an excellent flow-structure. Quartz-grains and porphyritic untwinned felspars form "eyes" in the fluidal and banded groundmass, and have been sometimes broken up and faulted during the intrusion of the mass. An attempt has been made to shear the dyke subsequently at an angle to the direction of flow, and the small flakes of biotite have sometimes been dragged out along the new structural planes.

The occurrence of this rhyolite makes one expect some intermingling with the diorite series; and the rock with pink felspar certainly attracts attention. Mr. Nolan† probably had this in his mind when he wrote of the occurrence of orthoclase in the gabbros; and we may well be influenced by his descriptions of the composite masses of Copney, Loughmacrory, and Craiggrena. But microscopic sections, aided by other observations, do not justify us in regarding the pink felspar of Oritor as derived from a granitic rock. It has a specific gravity of 2·63 to 2·65, which does not, it is true, remove it from the altered orthoclases of Slieve Gallion; but it is in places fairly preserved, and shows repeated twinning, both of the albite and pericline types. Few of the crystals in the two sections examined are suitable for the test of symmetrical extinctions; but the results obtainable favour labradorite as the species. This pink felspar is intergrown with masses of green secondary hornblende. Earth-pressures have deformed the rock, have bent the felspars, and have driven the chloritised amphibole into cracks running through the mass; but the fundamental and original structure has not been entirely obliterated. For comparison, a section was made of the ordinary diorite, with white "saussuritic" felspars, of the Oritor quarry. It is richer in hornblende, and the ophitic structure has a tendency to run into a pegmatitic one, as in the gabbros of Rum; but in this latter point it represents all the more closely the undeformed condition of the pinker rock. The latter must be regarded as having originally been a gabbro with much felspar, the opposite extreme being found in the diallage-rocks of Athenree. Its specific gravity is 2·87, as opposed to the 2·98 of the gabbro of Tullycall.

The white felspars of the ordinary Oritor diorite have an average specific

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* *Op. cit.*, p. 550.

† "Metam. Rocks of Tyrone," Geol. Mag., 1879, p. 157; also Mem. sheet 26, p. 15; compare pp. 12 and 13.

gravity of 2·70; but they range from 2·66 to 2·75, owing to their unsatisfactory state of decomposition.

The whole of the rocks at Oritor have received thrusts, which have in some cases produced partial brecciation, and in others a foliated condition. But the great dyke of rhyolite has not been broken through, nor have the relations of the other rocks been obscured. The evidence shows that a series of compact aphanites, or even andesites, were here invaded by a gabbro of medium grain, which was more felspathic in some parts than in others; subsequently the granite, which underlies so much of this district, sent up offshoots into the basic complex.

After examining these deep-seated masses, characterising so wide an area, I was hardly prepared to meet an apparently volcanic series, identical with that of Slieve Gallion, during a traverse of the country to the west. Gravel covers much of the surface as we follow either bank of the Ballinderry River; and, about Charles Town and Killeenan school, we enter the region of true micaceous gneiss. But, on the other side of this axis, we meet the sheer boss of Dungate Rock, accurately described by Portlock* as a dense rock of a green colour, with epidote and pyrite, and somewhat amygdaloidal. This mass obviously corresponds to the "pyroxenic rocks" of Slieve Gallion; even in its baked and flinty character, it recalls the andesites of Drummuck. In section, it proves to be an andesite, with porphyritic plagioclase felspars and green pseudomorphs of well developed pyroxene. Its peculiarity lies in the copious development of quartz in the groundmass, apparently filling up minute cavities, into which small rod-like felspars project. This quartz is no doubt secondary in origin; but it may be a product of contact-metamorphism, in which case the felspars of the groundmass grew out into the quartz areas as they formed. If it merely represents the infilling of a minutely scoriaceous rock, the angular cavities, and the projection of these felspars into them, seem at any rate unusual features.

In the open country on the north side of the road, good exposures of the diabase series occur, lying in the south of the townland of Beaghbeg. Some of these rocks are flinty and bedded, probably representing altered ash; others are vesicular†; others are of the dark type familiar on Tintagh Mountain. At the base of the series, in a ridge where the successive layers dip S.E., an aphanite or dolerite appears.

A very compact grey eurite, weathering white, and striking N.E. and S.W., comes up as a band in this series, and bakes the bedded rocks below and the andesite that overlies it. Veins of a similar rock stand vertically in the dark andesite of a neighbouring boss. Two-thirds of a mile to the west, well

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[*] *Op. cit.*, p. 545.

[†] Mr. Nolan describes vesicular rocks from near Creggan, and comments on their resemblance to those of volcanic origin (Mem. sheet 26, p. 14).

developed red-brown eurite, with porphyritic quartz, comes in as the edge of the important mass of Crockandun.

One band of the seemingly intrusive and highly siliceous series in the south of Beaghbeg is grey-green and almost translucent, and closely resembles an interbedded chert. This is probably the "hornstone" of Portlock.* I submitted a section from it, with those of cherts from Slieve Gallion, to Dr. G. J. Hinde, F.R.S., who has very kindly examined it. He writes that some of the clear patches in it "correspond in size and outline with radiolarian casts, but most of them are without any likeness whatever, and I do not think any of them are of organic derivation." This observation corresponds with the evidence in the field, and I feel confidence in referring this rock to the highly siliceous intrusive series. It was probably at one time an obsidian; and the ovoid bodies in it, more transparent than the ground in microscopic section, are most likely chalcedonic infillings of minute vesicles. Their arrangement along certain planes supports this view; and veins infilled by similar chalcedony traverse the whole mass.

I fear, then, that we lose even this rock as a possible marine sediment; and the dark schistose rocks of the higher part of the townland are even more certainly volcanic. The very summit of Beaghbeg is formed of a rudely fissile dark grey rock, resembling a poor slate passing towards the phyllite stage. A section of this proves it to have been once a trachyte, with a groundmass like that of the familiar rocks of Ischia; and porphyritic crystals of orthoclase and of a triclinic felspar are embedded in it. The minute green crystals of the groundmass, which was once fairly glassy, are probably soda-augite, porphyritic representatives of which are absent. The rock has now a specific gravity of 2·69, lower than that of the andesites of Slieve Gallion, and is, in my experience, unique in the whole area examined.

Below this trachyte on the crest, and also beside the stream bordering on Meenascallagh, the remarkable "breccias" of Beaghbeg are exposed. These are well described by Mr. Nolan† in their aspect in the field, and by Sir A. Geikie,‡ who states that they pass into "green schists," like those of Argyllshire and the central Scottish highlands. Sir A. Geikie regards these beds, with those of Creggan Lough, as volcanic agglomerates, containing both acid and basic rocks; and he points out the occurrence of vesicular structure in the blocks, when seen in microscopic section. Messrs. M'Henry and Watts§ also refer to these rocks as probably volcanic products.

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* *Op. cit.*, p. 533.

† "Metam. Rocks of Tyrone," Geol. Mag., 1879, p. 157; compare those near Creggan Lough, Mem. sheet 26, p. 14.

‡ Anniversary Address, Quart. Journ. Geol. Soc. Lond., vol. xlvii. (1891), *Proceedings*, p. 77.

§ *Op. cit.*, p. 59.

In Beaghbeg, the agglomerates have suffered so greatly from crushing, that I am prepared to find them transferred in certain quarters to the growing group of crush-conglomerates.* But, like the tuffs of Windy Castle, they contain blocks of more scoriaceous character than the rocks immediately round them, and in section show abundant fragments of andesite-glass, such as ordinarily occur only in tuffs. The variety of rocks present, including some "felsites," is also in favour of a volcanic origin. I would, indeed, go so far as to urge that the crushing, and the permeation by veins of quartz, have actually obscured the original fragmental structure. The mass has, in fact, been compressed, and to some extent foliated, until it resembles many of the rolled-out tuffs of Wales.

Opposite the farm of Keragh, in the east end of Beaghbeg, great masses of the typical hornblende-diorite (altered coarse-grained gabbro) jut out on the surface, seamed by veins of granite and of eurite. This fact will serve to complete the evidence of similarity on both sides of the gneissic axis, and of the essential relationships between the rocks west of Cookstown and those of the *massif* of Slieve Gallion (Pl. XIV., fig. 6).

V.—CONSIDERATIONS ARISING FROM A SURVEY OF THE PLUTONIC ROCKS ON AND NEAR SLIEVE GALLION.

In the moorland west of Oritor, we seem to get down to the roots of the volcano, the surface-manifestations of which are seen on the plateaux of Slieve Gallion. On the latter mountain itself, we have glimpses of the underlying coarsely crystalline rocks, in the diorite bosses of Letteran and Mobuy. But these are merely residual, and the great mass of the Slieve Gallion granite has either concealed or absorbed its basic precursors. In the western moorland, on the contrary, the gabbros survive, interestingly associated with lavas, and even tuffs, belonging to the same basic series. The granite is down below them, sending off abundant veins; but the struggle between the two types of rock can be examined here across miles of country, and the mastery of the granite has been by no means absolute.

A consideration of the aplitic granite of Carndaisy Glen, of the general poverty of the eurites in ferromagnesian constituents, and of the veins of pure soda-orthoclase that occur in the neighbourhood of Oritor, make me venture on a somewhat bold suggestion. The invading granite magma may originally have agreed in composition with the eurites, and would have crystallised as a virtual aplite; and it may owe even its green micas, as well as its occasional richness in hornblende, to the pre-existing gabbros that it absorbed.† The variations of a granite mass, in

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* Compare M'Henry, letter in *Nature*, vol. liii. (1895-6), p. 414; also Sir A. Geikie, "On some Crush-conglomerates in Anglesey," Geol. Mag., 1896, p. 481; and letter by Prof. Blake, *ibid.*, p. 569.

† Similar questions relating to the granite of Aydat, in Auvergne, were dealt with by M. Michel Lévy,

relation to the rocks locally in contact with it, were insisted on by Portlock and other geologists of his day; and, without reverting to the old and once natural view of the direct metamorphic origin of granite, may we not come to regard our complex plutonic rocks as in themselves phenomena of contact? The underlying magmas, hidden from us, may be of far simpler composition than we commonly suppose; and the so-called fundamental rocks of the earth's crust may be due to commingling in what are, after all, its merest surface-layers. Prof. Sollas's* statement that "the heated material of the interior is already in all probability in a high state of differentiation" seems to me an expression of belief in the simplicity of fundamental magmas, and affords strong support to the view above put forward.

Against this view, however, it may be urged, that the constitution of meteorites seems to give us a clue to the internal constitution of the earth, and that these bodies are often composed of complex silicates. Yet the great "holosiderites," consisting of alloys of metallic iron and nickel, point in the opposite direction, and indicate the existence of magmas of almost elementary composition. It seems, therefore, worth considering whether the mineral complexity of a plutonic rock, as we know it near the earth's surface, does not depend upon the number of times that it has been remelted and brought into new chemical environments; or else upon the number of times that it has been permeated by new magmas arriving from below. In the former case I picture it as absorbing something round about it; in the latter case, as being itself practically absorbed.

The late Mr. Hugh Miller† recently observed granites in Upper Strath Brora, in Sutherland, which replaced, in his opinion, a group of schists, while preserving the structural characters of those rocks. "Parts of these granites," he wrote, "are, in fact, pseudomorphs, or granite-casts, preserving, as replacement-structures, remains of the structure of the pre-existing rock." Messrs. Horne and Greenly's own paper, cautious as it is, opens up afresh the old field of progressive metamorphism. By combining the evidence that we possess as to local absorption with that urged in favour of differentiation within molten plutonic masses, we may arrive at the following possibilities:—

(i.) A molten magma may attack a pre-existing and usually overlying series

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with conciseness and lucidity, in 1890 ("Compte-rendu de l'Excursion du 17 septembre à Aydat et à Murols," Bull. soc. géol. de France, 3me sér,. t. xviii., p. 915); and he further emphasised his conclusions in 1896 ("Sur quelques particularités de gisement du porphyre bleu de l'Esterel; application aux récentes théories sur les racines granitiques et sur la differenciation des magmas éruptifs," *ibid.*, t. xxiv., pp. 124, 126, and 137). On p. 137 he writes: "On constate fréquemment . . . une action endomorphe subie par les roches granitiques, qui se chargent de certains éléments de leurs salbandes."

* "Relation of Granite to Gabbro at Barnavave," Trans. R. I. Acad., vol. xxx. (1894), p. 509.

† Quoted by Horne and Greenly, "On foliated granites and their relations to the crystalline schists in Eastern Sutherland," Quart. Journ. Geol. Soc. Lond., vol. lii. (1896), p. 635.

of rocks by a process of absorption, in some cases so complete as to resemble solution.

(ii.) It cannot do this unless space is made for the product of mingling, which, of course, need not equal in volume the united volumes of the invading and absorbed materials. Provision for this is very often made from the outset by the formation of a dome in the superincumbent rocks, the earth-pressures that give rise to this dome being usually responsible for the simultaneous flow of molten matter into it.

(iii.) The product of mingling may finally begin to crystallise, and the "plutonic rock" in due time presented to us is thus chemically different from that which the invading magma alone would have produced. It is also likely to be more complex in its mineral constitution.

(iv.) But, during consolidation, differentiation, from various causes, may be set up in the mingled magma, and the whole of the absorbed material may, in exceptional circumstances, become drained away, and may disappear into the depths, leaving a rock as pure, or almost as pure, as that which the invading magma would have formed before contamination.

(v.) Hence a plutonic mass may be a pseudomorph of the rock invaded by it, progressing inch by inch so long as it remains molten. It may be as truly a pseudomorph as flint is of massive limestone; but it seems improbable that original structures would, in such extreme cases, be preserved. In ordinary cases, flakes of the pre-existing rock may remain, and may mark out the old structure; the masses cited by Mr. Hugh Miller are possibly of this description.

(vi.) A plutonic rock may thus appear to have arisen as the product of metamorphism of a series of rocks *in situ*, in which case the plutonic mass seems actually to occupy the space once filled by a portion of that series. Where, indeed, the pre-existing rocks are not arched over the plutonic mass, either metamorphism or absorption seems the only way out of the difficulty. The older geologists set aside the chemical difficulties in such cases as Slieve Gallion, and urged metamorphism *in situ* as the cause of the plutonic core. I have tried to show above, that absorption is possible, but may be accompanied by transference of much of the absorbed material. The final igneous mass, on consolidation, may therefore be a true pseudomorph, and not a paramorph, of the rocks replaced by it.

If the foregoing considerations are accepted as a contribution to the discussion of Messrs. Horne and Greenly's remarkable Paper on the foliated granites of Sutherland,* it is all that I can fairly ask. They arise, however, naturally out of the problems presented by Slieve Gallion.

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* *Op. cit.*, Discussion, pp. 648-650.

VI.—Geological Age of the Rocks of Slieve Gallion.

Fortunately, there can be no dispute as to the geological age of the younger rocks of Slieve Gallion North, *i.e.*, the basaltic capping, and the Cretaceous beds protected by it. We have noted, in the first section of this Paper, how the red sandstones of the northern face, once regarded as Triassic, have now been referred to the Lower Carboniferous Series. But great uncertainty still exists as to the age of the older igneous masses.

The granite is obviously the younger of the two igneous series. Portlock* reports pebbles, closely resembling the igneous rocks of Slieve Gallion, in the Silurian (Llandovery) conglomerates of Lisbellaw, in the county of Fermanagh, and, on a later page, indicates that granite occurs among them. But this evidence, from a somewhat distant point, may be regarded as of doubtful value, in face of that obtainable nearer to the mountain. I hope, however, at some future date, to examine the conglomerates near Pomeroy,† which are said by Mr. Nolan to occur among Ordovician strata.

So many masses of granite in Ireland were intruded after the close of the Ordovician period, and before the Upper Old Red Sandstone was laid down, that one is tempted to place the granite of Slieve Gallion among them. It resembles the coarser parts of the Crossdoney mass, near Cavan, which are seen, for instance, at Bellahillan Bridge; and Mr. Nolan‡ believed, in 1878, that the granite of Slieve Gallion, and that near Pomeroy and Beragh, were portions of the same mass. The latter rock, north-west of Carrickmore, or Termon Rock, is seen to be intrusive in the Lower Old Red Sandstone. On the other hand, the officers of the Survey point to the granite *débris* in the Lower Carboniferous strata near Moneymore, as affording evidence of the minimum age of the intrusion. Hence it seems highly probable that the second igneous series of Slieve Gallion, and of the moorland to the west, is of Middle Devonian age; in that case it was associated with the earth-movements that produced so marked an unconformity between the Lower Devonian (Dingle Beds) and the Upper Devonian (Upper Old Red Sandstone).

But does this remove the granite from any connection with the gneissic axis which divides the two bands of the diorite series west of Cookstown? The gneiss may or may not be the source of the granite veins in that area; the point is obviously one of great interest, and I have not yet studied it in the field.

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* "Geol. of Londonderry," pp. 232 and 537. See also Mem. sheet 45, p. 10, where one block of granite is referred to Donegal.

† Geol. Surv. Mem. sheet 34, p. 13.

‡ Mem. sheet 34, p. 15.

Mr. Nolan[*] in 1879 made the brilliant suggestion that the granite intrusions were the result of the depression and remelting of the ancient metamorphic series; the mass thus flowed as an igneous rock, though originally it was of metamorphic origin. In this he anticipated the work of Dr. A. C. Lawson[†] in Canada, who proved that the Laurentian gneiss sends off granitic veins into the "later" Coutchiching and Keewatin series, and has even appropriated into its own body portions of those series. Mr. Nolan's hypothesis is thus an admirable working one, and may yet lead to the connection of Middle Devonian granites with the ancient Archæan floor.

In 1884, however, the same writer,[‡] in his official memoir, placed both the granite and the gneissic core to the west as "probably of pre-Cambrian age," thereby doing some injustice to his previous writings. He appears to have been impressed with the evidence of gradation from the granite into the "pyroxenic rocks," and to have been unwilling to regard the granite series as posterior to the latter. We may be pardoned for accepting his earlier reading of 1878, while reserving our opinion as to the connection between the intrusive granite and the gneiss.

The age of the basic series, volcanic and plutonic, is far more obscure. On Slieve Gallion itself, it has been regarded as consisting of metamorphosed Ordovician sediments; and it may even now prove to be a part of the great eruptive series, which characterises the Bala epoch in Ireland as well as in North Wales. Mr. G. H. Kinahan[§] has referred these rocks, with some hesitation, to the Arenig epoch; and it is claimed, as we have seen, that they graduate into the series of schists that culminates in the Sperrin Mountains. In the combe at the head of the Letteran Hollow, an iron-stained bed of chert occurs at the base of the andesites, dipping north-east; and other cherts, red and green, are found along the hæmatitic horizon in the neighbourhood of Tory's Hole. I had hoped that these deposits, which are sometimes minutely speckled with white spots, would have given microscopic evidence of their origin; but sections have proved most unsatisfactory. The chert found near Tory's Hole, in the Derryganard Hollow, contains many flakes of chlorite, and may be merely a chalcedonic replacement of a diabase along the zone of deposition of the iron-ores. Such a replacement is not unknown among basic rocks; the variolite of Ceryg-gwladys in Anglesey has even retained, under such circumstances, all its original structures. Similarly, the chert of Letteran may represent merely a phase of alteration in connection with

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[*] "Rocks of Tyrone," Geol. Mag., 1879, p. 159.

[†] "Report on the Geology of the Rainy Lake Region," Ann. Rep. Geol. Surv. Canada for 1887 (1888), p. 139F.

[‡] Mem. sheet 26, pp. 10 and 15.

[§] "Economic Geology of Ireland," Journ. R. Geol. Soc. Ireland, vol. viii., p. 160.

the mineral veins, or may be a feature of the actual walls of those veins. The hæmatite found upon the mountain contains, indeed, abundant drusy cavities lined with quartz. Dr. G. J. Hinde, F.R.S., reports as unfavourably concerning these cherts as he did concerning the siliceous rock of Beaghbeg. Certain "clear spots with curved outlines" in the chert of Letteran have to him "the appearance of being organic"; but "they are certainly not radiolaria even if they are organic." Dr. Hinde, moreover, in the same letter, states that he recognises no likeness between these spots and any organisms, siliceous or calcareous, known to him.

The schistose series to the north at present remains included in the "Dalradian" of Sir A. Geikie.* It is thus by no means absolutely removed from the Ordovician: nor, on the other hand, is much encouragement held out that it will be proved to be later than the Archæan era. Sir A. Geikie† places the tuffs of Beaghbeg at the base of the local Dalradian series, and regards the gneiss below as comparable to the Lewisian, that is, as genuinely Archæan. It is perfectly possible, then, that the basic series of Slieve Gallion, which must stand or fall with that of Beaghbeg area, may be entirely Archæan, as Mr. Nolan was prepared to believe in 1884. It is stated‡ that the "chloritic schists" overlie the pyroxenic series, and these schists are regarded in the same memoir as Ordovician. Thus Mr. Nolan connected the basic rocks with the supposed Archæan core, while Sir A. Geikie connected them, as almost everyone else seems to have done, with the "chloritic schists" themselves. It is safest to accept the happy mean offered us by the latter author, and to say that Slieve Gallion is formed of an eruptive "Dalradian" series, penetrated by a granite in Middle Devonian times.

[*Note added May 10th*, 1897.—Since this Paper was in the press, Sir A. Geikie has again treated of the Tyrone area in his "Ancient Volcanoes of Great Britain," vol. i., pp. 239–241. He now compares the volcanic series more closely with that of the southern margin of the Scottish Highlands, and places it as probably of Arenig age. The associated cherts "bear the closest resemblance to those of Arenig age in Scotland. But no recognizable Radiolaria have yet been detected in them." The gabbros are described as occasionally including portions of the "slaggy diabases." The Slieve Gallion area is not referred to; but the above remarks may clearly be extended to it, and will support those who would place the "Dalradian" chloritic schists also in the Ordovician system.]

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* Anniversary Address, Quart. Journ. Geol. Soc. Lond., vol. xlvii. (1891), *Proceedings*, p. 75.

† *Ibid.*, p. 77.

‡ Mem. sheet 26, p. 14.

VII.—CONCLUSION.

I may now sum up by setting down the following conclusions:—

(i.) The series of hornblendic and pyroxenic rocks on Slieve Gallion, hitherto described as of metamorphic origin, includes a volcanic series of andesite-tuffs and vesicular and compact andesites, together with their deep-seated representatives.

The age of this series is "Dalradian," using that term in its widest sense.

(ii.) The granite, also once held to be of metamorphic origin, is an intrusive mass, which has absorbed some of the basic rocks, and has produced quartz-diorites by a process of intermingling.

The period of its intrusion was pre-Carboniferous, and probably Middle Devonian, as stated by the officers of the Geological Survey.

(iii.) The basic series west of Cookstown, including the volcanic tuffs of Beaghbeg, is indistinguishable from that of Slieve Gallion, and is almost certainly of the same geological age.

The relations of this series to the gneiss that underlies it have yet to be satisfactorily worked out. The suggestion of Mr. Nolan, that the gneiss became remelted to provide the granite veins above it and the granite mass of Slieve Gallion, deserves the most careful consideration.

(iv.) The occurrence of aplitic granites and eurites on Slieve Gallion, associated with varieties rich in biotite and in hornblende, and the discovery of intrusive veins of pure soda-orthoclase near Oritor, suggest that even the biotite in the granite may have resulted from the absorption of the basic series by a magma that would otherwise have crystallised as an aplite; and, following on this, it is urged that the underlying magmas of the earth's crust may be of far simpler character than has been commonly supposed. Prof. Sollas's investigations at Barnavave seem to point to the same conclusion. It is then suggested that plutonic rocks, as we ordinarily know them, are phenomena of contact, produced in what are, comparatively speaking, the upper layers of the earth's crust.

(v.) By a combination of absorption and concomitant or subsequent differentiation, an invading igneous rock may come to occupy the place of a pre-existing rock, and may, in fact, represent it as a pseudomorph, the absorbed matter being drawn off through the molten mass to lower levels.

Lastly, I would express my obligations to all those who have helped me, by advice or in the field, including Mr. J. Nolan, Mr. A. McHenry, Dr. G. J. Hinde, F.R.S., and Sir Wm. Lenox Conyngham, K.C.B., of Spring Hill, Moneymore; and to my Wife, for the determination of many of the specific gravities recorded in the present paper.

EXPLANATION OF PLATES XIII. AND XIV.

PLATE XIII.

View of Slieve Gallion from the south-east, coloured to show the distribution of the various igneous and sedimentary series.

PLATE XIV.

Fig. 1. Microscopic section of augite-andesite tuff, from flinty and bedded mass above Craigmore, Slieve Gallion. The left hand upper portion shows a lump of andesite with porphyritic felspar; the right-hand lower mass is amygdaloidal. The fine ashy ground, with signs of compression and flow, is seen in the interspace. × 10.

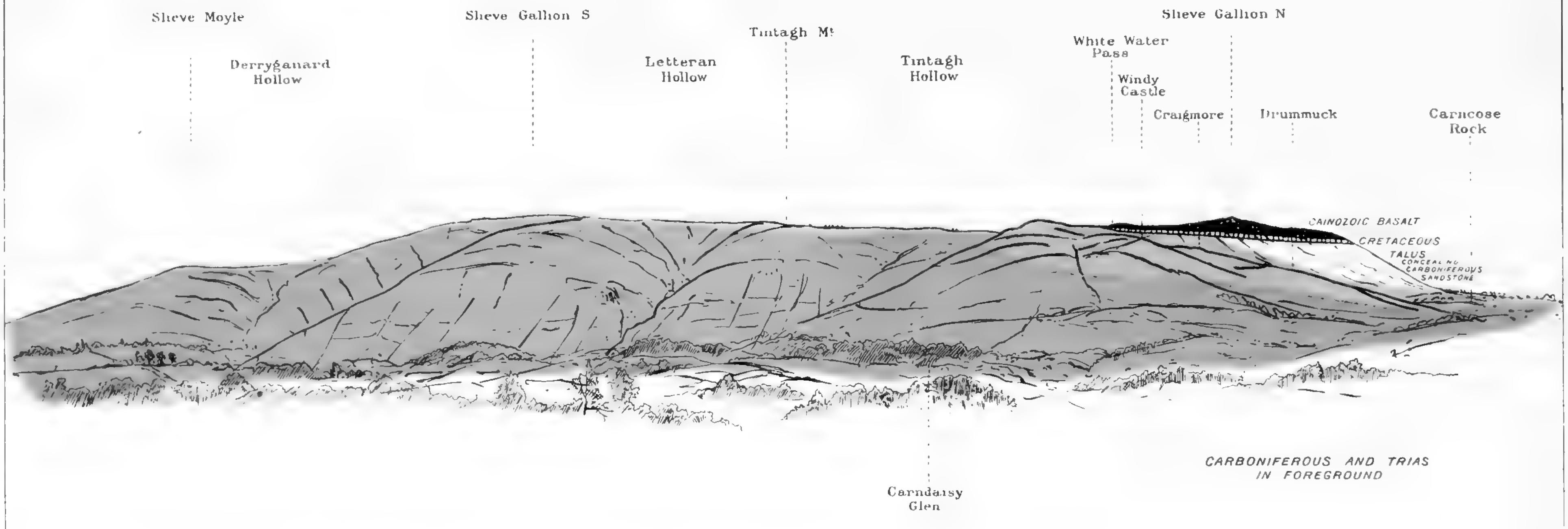
Fig. 2. Microscopic section of rhyolite, from dyke in Oritor Quarry. A porphyritic felspar, with small corroded quartz-grains above it, occurs in the left-hand upper portion. The flow-structure is more distinctly seen in the original. × 8.

Fig. 3. Microscopic section of hornblende-diorite (altered gabbro) penetrated by veins of micropegmatite, from boulder on S.W. slope of Glenarudda Mountain, Slieve Gallion. The normal structure of the diorite, with its "saussuritic" felspar, is seen below; while the invasion of the micropegmatitic magma, in the upper part of the section, has induced a free and idiomorphic crystallisation of the hornblende of the rock attacked by it. × 8.

Fig. 4. Microscopic section of hornblende-diorite penetrated by micropegmatite, from Letteran, Slieve Gallion. In contact with the quartz of the micropegmatite, the hornblende has assumed its characteristic outlines, although it occurs in a fibrous uralitic condition in the other parts of the rock. The original plagioclastic felspars have also renewed their growth in many places, as may be seen with a higher power. The rock is an example of a quartz-hornblende-diorite produced by admixture of an altered pyroxene-diorite (or gabbro) and a granite magma. × 11.

Fig. 5. View of dyke of pink rhyolite traversing basic rocks at Oritor Quarry (see fig. 2 above). The dyke runs obliquely upwards from the right.

Fig. 6. View of part of bosses of altered gabbro, traversed and highly penetrated by veins of micropegmatitic eurite and aplitic granite. Opposite the farm of Keragh, Beaghbeg, Co. Tyrone.



☐ ANDESITE AND DIORITE SERIES.

▨ GRANITE AND EURITE SERIES.

SLIEVE GALLION,
from Moneymore.

G. Cole del.

McFarlane & Erskine, Lithrs Edinr

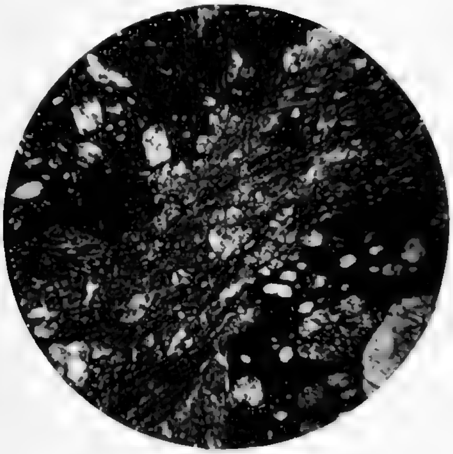


Fig. 1.

Fig. 2.

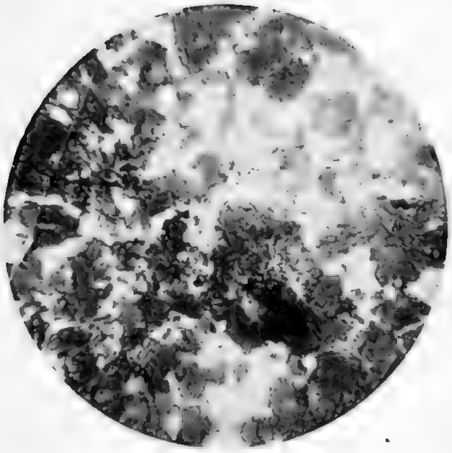


Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

ROCKS OF SLIEVE GALLION AND E. TYRONE.

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THE

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By J. JOLY, M.A., B.A.I., Sc.D.,
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(Plates XV. and XVI.)

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[Read January 20, and March 24, 1897.]

The confirmation which Professor Schiaparelli's observations have received in the careful study of Mars' surface made by Mr. Percival Lowell and his colleagues, Mr. D. E. Douglass and Professor W. H. Pickering, has justifiably raised the problem of the origin of the "canals" of Mars to a level of much interest and serious importance. Our present knowledge of the appearance of the Martian surface certainly justifies speculation as to the cause and nature of that appearance, so unlike anything with which observations, either upon our own Earth, or upon other heavenly bodies, has made us acquainted with. The double lines, and the strange doubling of these lines, first observed by Schiaparelli, have been fully substantiated, not only by the observers of Flagstaff Observatory, but by many others observing under favourable conditions. Mr. Douglass has added the important observation that the curved lines traverse the dark areas as well as the light areas of the planet's surface. The general course and character of the curves appear the same in the observations of Lowell and Schiaparelli, where these observations overlap. The presence of peculiar round dark patches upon the lines marking their points of meeting and crossing, although, as might be expected from the better conditions of observations at an altitude of 7000 feet in Arizona, more definite in Mr. Lowell's observations, is yet substantiated in Schiaparelli's maps. The curved rifts crossing the polar snows have been observed by many independent observers.

Finally, it will be found, further on in this Paper, that the curvature of the lines, mapped by Lowell, agrees, in a remarkable manner, with a certain theory of the common mode of origin of these lines—a mode of origin which would at once account for their curvature and for their peculiar appearance as double or even triple lines. While this agreement of observation and theory is at once a support to both, I thus early wish to say that what is advanced in this Paper can claim no higher value than that of being a speculation. Until its details have been further investigated, and until we possess a more minute knowledge of the planet's surface, it must remain a speculation. But, just because of the desirability of this further investigation, and as the only rival speculation equally comprehensive is the theory of the artificial origin of the canals, I think its publication justified.

It is supposed, in the hypothesis put forward in this Paper, that Mars, at various times in his past history, captured small satellites, which, after circulating round him for longer or shorter periods of time, fell into him. The phenomena of the lines, double or triple, are the result of the proximity of such bodies. The captured bodies must have been comparable in size with the larger asteroids at present circulating in mean orbits outside that of Mars. They may have been something between the dimensions of Phobos and Ceres. The phenomena giving rise to the lines would, probably, involve a proximity of less than one hundred miles separating the surfaces of planet and satellite.

The theory further assumes that the axial angular velocity of the planet was not always that which it at present is. To account for the differing curvatures of the lines, as will be seen later, it must be assumed that Mars' day was once much shorter than at present. It must also be assumed that some of the captured satellites were retrogade to the planet's axial rotation, and some direct; the greater number being retrograde.

A word is to be said in defence of these assumptions on *a priori* grounds.

The most accredited theory of the origin of the belt of asteroids is, that these bodies are a misbegotten world: the *débris* of a ring of nebulous matter thrown off by the Sun before his circumference shrunk to that of Mars' orbit. This view is, of course, the direct application of Kant's hypothesis to their mode of origin. If this represents the facts, then we must suppose that the asteroids were once far more numerous than they are at present known to be. According to Proctor, it would require 125,000 bodies, having the mass of Ceres, to make up our globe.* Only some 400 asteroids, in the mean much smaller than Ceres, are known. It is also justifiable to assume that the mass of the nebulous ring, which gave rise to these bodies, was comparable with that of the ring which gave rise to Mars, or our Earth. In either case, many tens of thousands of asteroids are missing.

The known asteroids are peculiar in their orbits, both in respect to excentricity and to inclination to the ecliptic. The excentricity is so considerable in some

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* "Old and New Astronomy," p. 554.

cases, that it has been asserted that some of these bodies actually come within Mars' mean distance of the Sun, and move to distances beyond the orbit of Jupiter.* Is it not probable, then, that in the past both Mars and Jupiter may have drawn from their orbits, and picked up some of these minute wanderers? This suggestion is not altogether new; Mars' present satellites have been ascribed to this source.

The assumption of the slowing down of Mars' axial velocity needs no justification here. Solar tidal influence must always act in this direction. If many small bodies, especially if rotating retrogradely to the planet's axial motion, were at various times absorbed, this would be also a cause of diminished axial rotation—a diminution, of course unknown in amount, but probably small.

Gravitational effect of a Small Satellite moving close to the surface of a Planet.

A small solid satellite, moving close to the surface of its primary, will give rise to certain stresses in the crust of the latter, due to gravitational attraction. What the magnitude and distribution of these stresses will be when the satellite is moving relatively to the planet's surface at a very high velocity is a problem not touched upon in this Paper. The case of the satellite moving slowly, relatively to the surface of its primary, or at rest, relatively to this surface, is alone dealt with. The importance of dealing with this question is, of course, to find if the tidal disturbances of minute satellites are likely to affect the crust in a manner calculated to give rise to such appearances as are presented by the double "canals" of Mars.

Immediately beneath the satellite the gravitational pull of this body is all vertical in direction; outwards, from this point, the force acting upon the surface material is a pull directed towards the satellite's centre. Resolving this force at any point into a vertical and a horizontal component, the first goes to elevate the solid crust of the planet in a very feeble degree; the second tends to pull it in beneath the satellite. The latter adds up as we go outwards, one particle pulling upon the next one. The tensile stress thereby set up is, however, at the same time diminished owing to the increased area over which the total force is distributed. The integration outwards shows that there is, as was to be anticipated, a circle of maximum stress, the circular base of a cone having the centre of the satellite at its apex, the semi-angle of the cone being closely 71°. It is assumed that the crust is insufficiently thin, and so far affected by the central lifting force as to be unstable under horizontal compression.

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* Proctor, *loc cit.*, p. 560.

The equation determining the stress at any point is found as follows:—

The force at any point on the elementary ring assumed one c. m. deep (fig. 1), is $\frac{\mu}{r^2}$; the horizontal component per elementary volume is

$$dh = \mu \frac{\rho}{r^3} \,.\, \rho d\alpha \,.\, d\rho$$

$$= \mu\delta\alpha \,.\, \frac{(1 - \cos^2\theta)}{\cos\theta};$$

$$h = \mu\delta\alpha\left(\int\frac{d\theta}{\cos\theta} - \int\cos\theta d\theta\right)$$

$$= \mu\delta\alpha\left(\log\tan\left(\frac{\pi}{4} - \frac{\theta}{2}\right) + \sin\theta,\right);$$

$$\text{stress} = \frac{h}{\rho\delta\alpha} = -\frac{\mu}{a}\left(\frac{\log\tan\left(\frac{\pi}{4} - \frac{\theta}{2}\right) + \sin\theta}{\tan\theta}\right). \qquad (1)$$

This is a maximum when

$$\frac{7}{4}\sin\theta - \frac{\sin 3\theta}{4} + \log_e \tan\left(\frac{\pi}{4} - \frac{\theta}{2}\right) = 0.$$

From this the maximum value of the stress is found to correspond to a value of $\theta = 71° 5'$.

To construct the curve of stress, the values of that part of (1) enclosed in brackets for different values of θ are calculated:—

θ	$\frac{\log\tan\left(\frac{\pi}{4} - \frac{\theta}{2}\right) + \sin\theta}{\tan\theta}$
10°	0·011
20°	0·038
30°	0·088
40°	0·144
50°	0·206
60°	0·261
70°	0·290
80°	0·256
85°	0·186

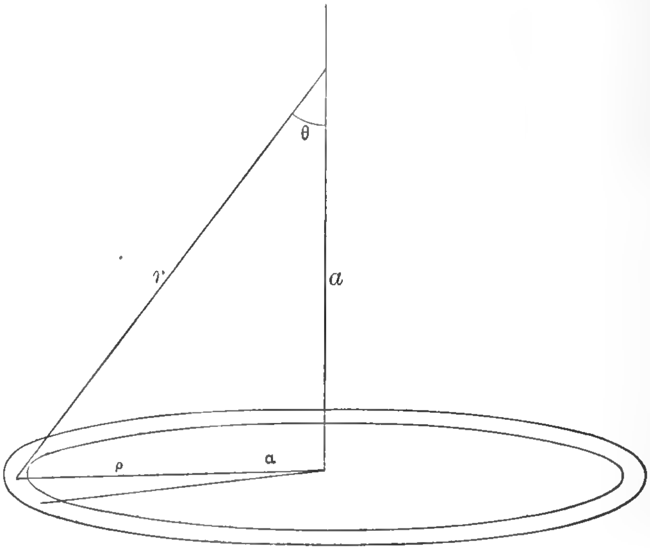


FIG. 1.

It remains to assign a value to μ and to a.

If, looking forward to the time when Phobos, according to lunar theory, will have drawn nearer to the surface of Mars, and be about to share the fate of many predecessors, we assume Phobos to be the satellite responsible for the stresses under consideration, we must still assign at a guess a density to the satellite.

His radius we take as 18 miles (Lowell's number), and we assume his density to be four times that of water. His mass is, on these data, 4074×10^{17} grammes. Taking the constant of gravitation as

$$\frac{1}{1543 \times 10^{4}} \text{ dynes,}$$

and assuming his attractive force to be concentrated at his centre, and acting upon a mass of one gramme placed at a distance of one centimetre from this point, we get

$$\mu = \frac{4074 \times 10^{17}}{1543 \times 10^{4}} \text{ dynes.}$$

We may assign to a such a value that the maximum stress will act upon a circle 220 miles in diameter, which is the width of the wider double canals. This will require a to be 38 miles. Twenty miles will then separate the surfaces of planet and satellite. The constant depending upon θ is 0·29 for the circle of maximum stress, very nearly; and a is 38×160923 centimetres. If the surface density of Mars is three times that of water, and the unit of mass be taken as the mass of one cubic centimetre of his surface material, we find finally, in grammes per square centimetre,

$$\text{Stress} = \frac{4074 \times 10^{17}}{1543 \times 10^{4}} \cdot \frac{3}{38 \times 160933 \times 981} \cdot 0{\cdot}29$$

$$= 3828 \text{ grammes, or about 7847 pounds to the square foot.}$$

The following Table determines similarly the stresses at various angular distances from Phobos:—

θ	Stress in grms. per sq. cm.
10°	150
20°	508
30°	1167
40°	1904
50°	2724
60°	3445
70°	3830
80°	3380
85°	2462

These are plotted in the accompanying curve (fig. 2, p. 255), the vertical ordinates of which gives the magnitude of the stress at different distances along a radial line drawn outwards from beneath Phobos.

If we assume Phobos to be a captured asteroid and to represent one of the high-density class of meteorites, we may ascribe even double this stress to his future proximity to Mars' surface.

The gradual slope of the curve near the point of maximum stress, rather suggests 60° as marking out the circle of effective stress if there is relative motion of planet and satellite. The anchoring effects on the crust of inertia and viscosity (supposing the planet's crust to be underlaid by a viscous magma) will be less effective at this distance. After the 60° point the stress increases but little. In this case action at the radius of 110 miles will require the satellite's centre to be placed at a vertical distance of 63·5 miles. The stress varies inversely as the vertical distance of the satellite; and hence it will be found that the horizontal tearing stress per square centimetre will have diminished to 2062 grammes, the density of Phobos being 4. A satellite having a diameter double that of Phobos (a diameter still much less than that of the larger asteroids) will at the distance of 63 miles exert a stress of from 15 to 30 tons per square foot, according to what assumption we make as to the density of the body, tending to rend the crust or surface material of the planet in a circle 220 miles in diameter.

We have next to consider the probable effects of such a stress when the satellite is moving relatively to the surface of the planet, but not at such speeds as to seriously interfere with the establishment of static stresses.

The satellite must be considered as carrying the circle of stress along with it over the planet's crust. Tangents drawn to this circle, parallel to the direction of the line of motion, define two lines 220 miles apart. Along these lines the stress is advancing, increasing from zero at points very remote from the satellite up to the maximum amount, and again dying away. Directly in the line of advance of the satellite itself, the rate of change of stress is much greater. An action goes on, too, along the tangents which does not go on in the central line: a *tearing* action if a crack is once started. Thus, suppose such cracks started when the satellite is passing over a weak spot in the planet's crust. The advancing extremities of the cracks are now continually the site of concentrated forces, coming in for the stress acting on the already gaping walls of the crack. For the same reasons that we go to the edge of a piece of cloth in order to tear it, and do not waste our exertions upon the middle of it, the stress upon the edge of the crust will tear it, although possibly not great enough to be effective when applied to a sound part of the crust.

The tearing action does not act in the same manner across the direct line of advance of the satellite; a line of weakness at right angles to the line of advance may open, perhaps, owing to the stress, but the effect of this is only to relieve the parts further on in the line of motion from intrinsic stresses and from those due to the satellite.

Hence the motion of the satellite is accompanied by two parallel lines of maximum stress carried over the planet's surface with each return of the satellite over the same ground. How long this repetition of the stress will continue is a

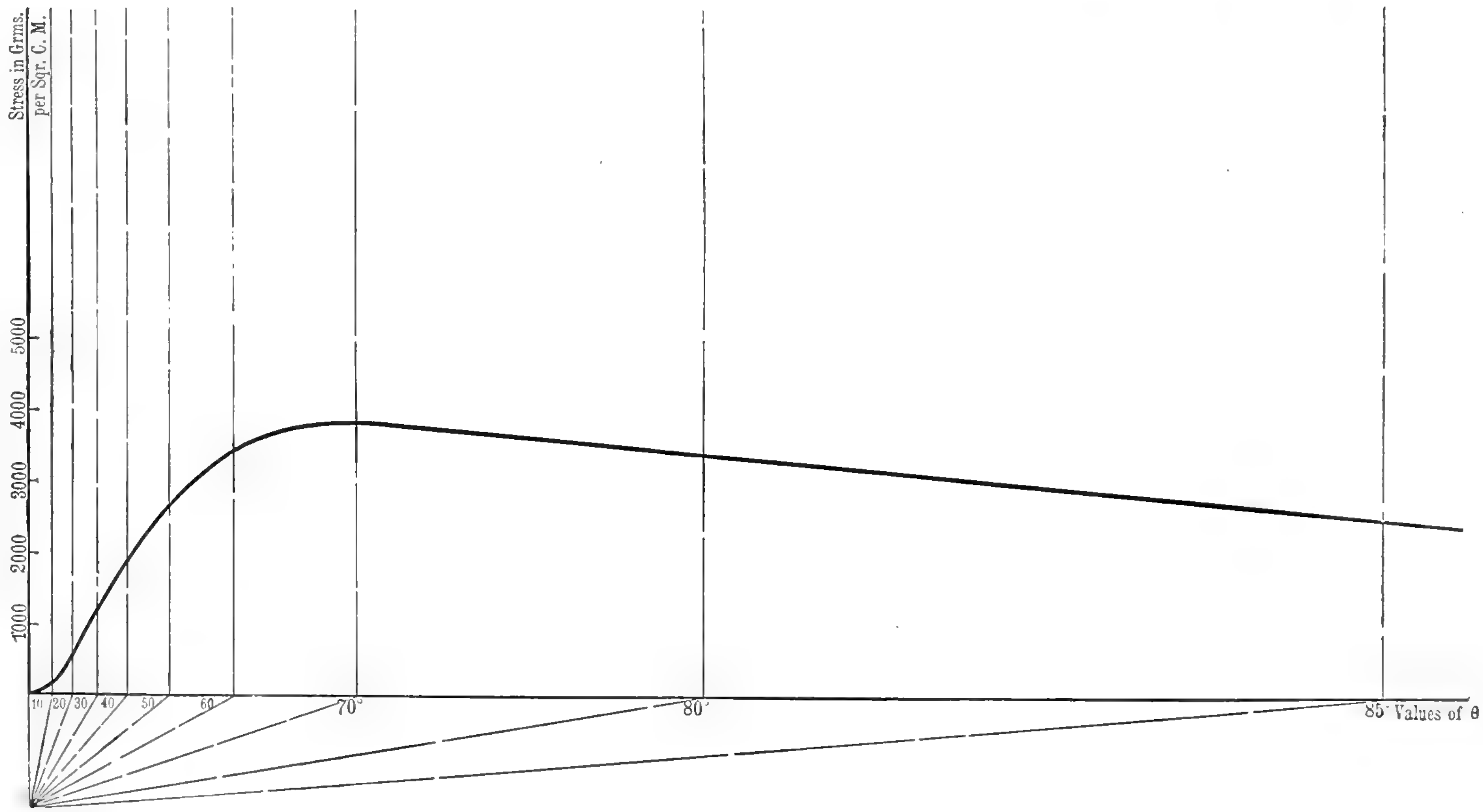


FIG. 2.—Horizontal Tearing Stress in the Planet's Crust.

matter of conjecture. For months, probably; possibly, for many years. This point will need further consideration later on.

If it be asked what record we may expect of such repeated stress in the crust, we can only answer that there is great probability that repeated disturbances of the crust will lead to eruption and upheaval if an energetic substratum underlies the surface crust. There is some reason to trace in certain cases terrestrial earthquake disturbances to the tidal action of our own satellite. The more local and concentrated tidal effects of small satellites close to a planet's surface should produce like seismic disturbances, but of more local activity. The path of the satellite will, in determining lines of weakness, probably be traced with upheaved districts similar to those which mark out many terrestrial coast lines which have themselves been referred to lunar attraction. Whether this view is in keeping with our present knowledge of the surface features of Mars will be considered further on.

We must not overlook what goes on immediately beneath the satellite's path of advance over the surface of its primary. We may assign to the vertical forces the function of elevating the crust in such a degree as, considered along with the instability of so thin a layer under compression, will allow us to disregard the elastic resistance to compression as seriously modifying the establishment of tensile stress in the regions without. But is it not probable that this very elevation will result ultimately in similar disturbances to those we may suppose will mark out the outer lines of stress? We have to consider more especially what will happen when once the tensile stresses have done their work. When this happens, the horizontal forces inwards will add themselves in part to the lifting forces, and assist towards producing central upheaval.

The difficulties attending the estimate of disruptive stresses to which the planet's crust is subjected when the relative motion of the satellite over the surface of the planet is very great, are so formidable that I reluctantly leave the problem unsolved. In the case of Phobos falling into Mars, when the satellite has attained the distance of 63 miles from the surface of Mars, his velocity will be somewhat over two miles per second. Taking into account the rotational velocity of Mars at its present value, the relative velocity will be very nearly two miles per second. Impulses will travel in the crust with the velocity of sound, and may therefore be assumed to travel outwards at the rate of three miles per second from points along the path of advance of Phobos. The addition of these waves will determine the magnitude and position of the lines of stress accompanying the satellite's motion. This high relative velocity is no extreme case. Some of the lines of Mars were, according to this theory, formed at even higher relative velocities. A particular case is that when the relative velocity is that of sound in the material composing the crust of Mars. In this case the effects will continually add up, the impulses travelling along with the exciting cause of fresh disturbances. The final result will only be controlled by the damping effects of viscosity. Such a condition may obtain when the satellite's motion is retrograded. It recalls Professor G. Darwin's suggestion for the origin of our Moon.

A rough geometrical examination of the conditions of summation of impulse waves at high velocities of the satellite relative to the crust appears to show that side lines, as in the static conditions, of maxima stress are formed, and this whether the satellite's relative velocity is greater or less than that of sound. *At* the velocity of sound it appears that an apical spreading wave alone is formed.

In cases of high relative velocity the question of the effects is complicated by the very different behaviour of materials under suddenly applied stresses. Many substances will break down under such conditions which would successfully resist greater stresses applied gradually. The effects of very rapid motion will be, we may expect, like that of an earthquake shock, in a small way. This shock will be repeated over the same ground with each return of the satellite. Phobos, when he has lessened his distance to some 60 miles from the surface of Mars, will accomplish his month in one hour and forty minutes.

Stability of the Satellite.

It is necessary to raise the question of the effects of this close approximation upon the satellite itself. Here again a full determination of the stresses is a matter of much difficulty. It is easy to show, however, that the rigidity of the satellite will most probably be more than sufficient to secure it against the effects of the stresses set up in it. Even if its resistance to tensile stress is no more than that of basalt, there is a large coefficient of safety. This may be seen by considering in a general way the stresses thrown upon the equatorial section of the satellite which is at any instant tangential to Mars' surface, due to the centrifugal force outwards acting upon the inner hemisphere being necessarily less than the attraction of the primary requires. We may consider the extreme case of supposing the satellite 23 miles from Mars' surface—that is with but 5 miles separating the surfaces. The velocity of Phobos is then 353,600 c.ms. per second. A mass of one gramme placed at the centre of gravity of the inner hemisphere is acted on by a force of 364·08 dynes. Assuming the acceleration of gravity upon the surface of Mars to be 981 × 38/100 dynes, Mars' attraction on this mass is 366·15 dynes; there is therefore an inward acting force of 2·07 dynes per gramme. Considering this as the mean force per gramme of Phobos' hemisphere, the stress per square centimetre on the equatorial section is 15×10^6 dynes; which is about $\frac{1}{7}$th the

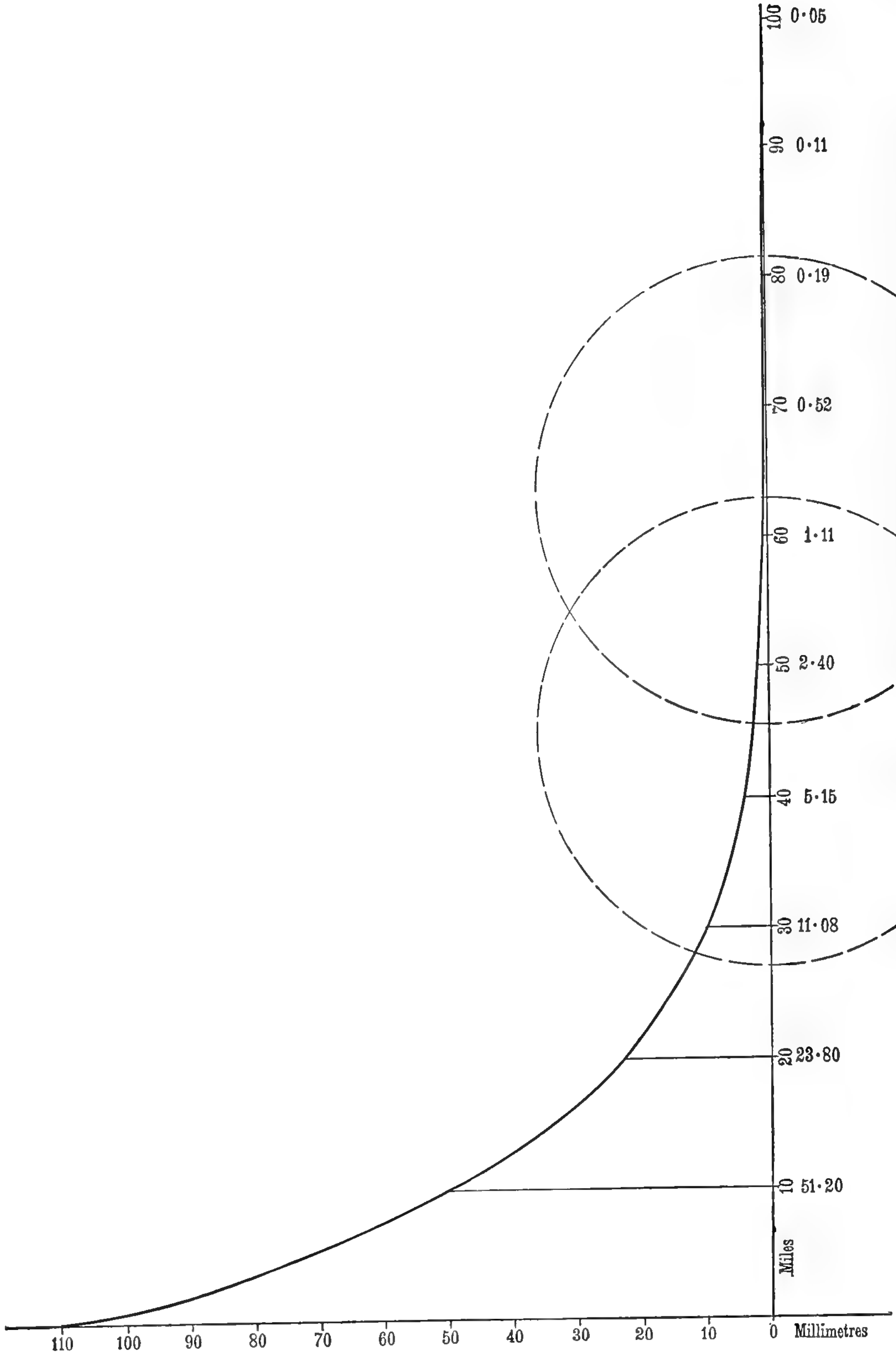


Fig. 3.—The distribution of atmospheric pressure above the surface of Mars.

breaking strength of basalt, and $\frac{1}{13}$ that of glass. A fluid satellite would not, of of course, be stable. In fact, a gramme mass placed upon the innermost point of Phobos' surface must possess a cohesive force binding it to the surface of Phobos of about 6 dynes. It is improbable that local stresses due to tidal action on the satellite can imperil its stability, seeing that the total stress falls so far short of the probable resistance to rupture of the material of the satellite. Further from the surface of Mars, the stresses are, of course, much less.

Effects of Mars' Atmosphere on the Satellites.

It appears certain that there is some atmosphere to Mars, and Mr. Lowell adopts the current view that this atmosphere is about one-seventh the density of our own. The effects of this as a resisting medium to the motion of a satellite need some remark. The accompanying figure (3, p. 258) shows the distribution of pressure above the surface of Mars. The pressures are given in millimetres of mercury supposed to be under terrestrial gravity. The temperature of Mars' atmosphere is assumed at 0° C. The circles show the disk of Phobos at two altitudes above the surface. At the height of 65 miles, it is seen that the pressure of the resisting medium is 0·8 m.m.

The effects of a resisting medium upon the fate of a satellite are well known. If the angular velocity of the primary is greater than that of the satellite the effect will be repulsive, diminishing at the same time the speed of the satellite. If the satellite rotates the faster of the two, the effect is the other way. Tidal action goes with and accelerates these effects. It is evident from the curve that the satellites' energy will be rapidly absorbed or increased at close distances. A long stay in either case near the surface of the primary is impossible. At a distance of 65 miles, and assuming the full pressure of the medium to retard the advance of Phobos, that is, assuming a perfect vacuum continually maintained in its rear, his spiral path will shrink from 75 to 55 miles after some 88 thousand revolutions, the satellite taking fifteen years to effect this approach. This estimate is obtained by considering the diminished value of the sum of the potential and kinetic energy of Phobos when he has fallen to within 55 miles of the surface, and assuming that this loss of energy is due to the retarding effect of the atmosphere doing work at a rate estimated from the satellites' velocity when at the mean distance of 65 miles.

During this period and subsequently the nodes of the satellite will probably be slowly shifting. The equatorial bulge of Mars, although small, will enter into this question, as well, probably, as even any considerable raised surface features of Mars.

Effects of the motion of the Satellite through an atmosphere as a cause of the lines.

It is remarkable that the presence of a satellite moving at such a distance from the surface of Mars as to be within Mars' atmosphere affords an entirely different mode of explaining the formation of the double canals, or even triple canals, supposing certain other not improbable conditions to obtain: an explanation depending upon the atmospheric disturbance set up by the motion of the satellite through the atmosphere, and the effect of this on loose surface material.

The photographic record of the compressional air-wave streaming back from a bullet advancing through the air at a velocity of a thousand feet per second, or more, is now familiar to everyone. The mechanical effects of such an atmospheric wave may be studied by directing the bullet over a surface of loose powder. Suppose, for instance, the bullet is fired close down over lycopodium or lime loosely dusted upon a plate of glass. It is found that the wind-track of the bullet consists of parallel mounds of powder which have been blown to either side from the central line. In many cases a central ridge is also raised to mark the passage of the bullet. The double or triple lines so formed present a remarkable uniformity of width and parallelism. In one of the experiments the bullet was a small pistol bullet, the velocity of which when passing over the powder was about 750 feet per second. The bullet passed at a height above the powder which, estimated by perforations left in cardboard sheets erected at opposite ends of the plate, was equal to a little more than its own radius, clear of the surface of the powder. The two elevated ridges resulting from the passage of the bullet through the air overlaying the powder were separated by a clearance having a width of two-and-a-half times the diameter of the bullet.

What the effects would be, even in a less dense atmosphere, if the bullet were magnified up to, say, fifty miles in diameter, and its speed increased to perhaps 20,000 feet per second, may well be imagined. Any loose material would doubtless be torn up and projected from the path of the satellite. The sand of an ancient ocean, or the disintegrated material due to weathering would be cleared off and banked-up in ridges not less than 150 miles apart.

The manner in which double canals are observed to cross each other, the lines of one being carried right across the central space of the other, might suggest a difficulty in the way of this mode of origin. But if it be considered that long intervals of time must have separated the formation of these canals, as will be seen later, during which disintegration from various causes would lead to the accumulation of *débris* upon the plains, and the consolidation of the accumulations of past disturbances, the appearance observed is no serious obstacle to this action being accountable, or in part accountable, for the canals.

Reasons for supposing that the lines are raised, and not depressed, upon the surface of Mars.

It thus appears as if two very different kinds of action arising from the presence of in-falling satellites might give rise to the double lines. In both cases we must infer that the canals are raised and not depressed upon the surface of Mars. It is necessary to say a word in support of this view based on other considerations.

In the first place, it appears as if there was nothing in the appearance of the lines to lead to the belief that they are necessarily depressed and not raised. The fact that mountains so high as those on the Moon have not been detected on Mars of course leaves it an open question as to whether the lines are raised ground of less elevation than this or not. Many observers have maintained that they are low mountain ranges. Mr. Schaeberle, some four years ago, questioned the oceanic nature of the dark markings. The light and shade upon these pointed, in his opinion, to a rough mountain country. He thought the light areas oceans, and the lines ridges standing up out of the water. It appears now very certain that neither the dark nor the light areas are at present oceanic. There is, in fact, no appearance of sheets of water upon any portion of the surface of the planet. Professor Barnard came also to the conclusion, at the opposition of 1894, that the dark areas were land. Mr. Lowell and his colleagues, although they question the existence of mountains as high as those on the Moon, frequently reported, during the period of their operations at Flagstaff Observatory, marks at the terminator which led them to think that there were mountains on the surface. That the shadows of mountains at sunrise or sunset might be of considerable extension, and still be invisible to us, may be judged from the fact, as stated by Lowell, that an object must possess a diameter of thirty miles in order to be visible to us. Again, the other mode of detecting the presence of mountains, that is, by their appearance as bright points within the dark edge of the terminator, will not probably be so effective in the case of Mars as in the case of our Moon. The effects of an atmosphere will be to diminish the brightness of such points of light, not only by diminishing the incident light, but also by absorption of the reflected light. It would appear, however, that this appearance has been seen upon Mars. The sensational "signal" seen in the dark limb of Mars in 1894 has been explained in this manner. It has been suggested that the mountain peak giving rise to the point of light was covered with snow or ice. From all this we see that, so far as observation goes, the idea is by no means precluded that they are in truth not depressed, but raised upon the surface.

But there is another argument for supposing that the lines are low mountain ranges—ranges probably under 10,000 feet in height. This is involved in the fact that in this supposition we find a comparatively ready explanation of the mysterious appearance and disappearance of the lines.

Something going on in Mars determines this coming and going of the lines. The changes are not sudden; and the conspicuousness of the lines appears attendant on the liberation of the polar snows of Mars. The white deposit upon the polar regions of Mars must represent but a shallow deposit of frost or snow. From Lowell's observations we find in fact that a period of twelve days sufficed to free many hundreds of thousands of square miles of its covering. And three months of the solar radiation at Mars (of but half the intensity of that received upon the Earth) sufficed to practically clear off the entire polar covering. It is very probable that this small amount of water (if such be its nature) will be for the most part, or entirely, diffused through the Martian atmosphere, and in this way gradually conveyed towards the equatorial regions. The diffusion of water in this manner will be greatly aided by the rarity of the Martian atmosphere. Mr. Lowell urges that it is improbable that rain or snow will form in so rare an atmosphere, but that the natural distribution of water will be by distillation from place to place, or by dew-fall. This is, it may be said, a certainty, if the atmosphere is indeed but one-seventh the density of our own.

In the serene atmosphere which observation appears to ascribe to Mars, his mountain ranges would exhibit phenomena depending upon aqueous distillation such as are only in a feeble degree familiar to our experience. In the extreme cold of the Martian night the water in the atmosphere would be precipitated principally upon the higher ground, which of course will first cool by radiation. This deposit will take the form of frost, which with the return of solar radiation will melt. In the Alps of Europe, travellers meet with this phenomenon on a small scale.

If it be the case, as Mr. Lowell thinks, that the light areas of Mars are now arid wastes, the effects of the daily liberation of water on the higher ground will lead to just such contrasting darkening of the ground as will render the "canals" conspicuous. An early riser in summer time will often see a fallow field similarly darkened by the dews of night. We must, in short, remember that, in a world wherein water is as scarce as it is supposed to be in Mars, the elevated ground would receive the larger supply of water. Our valleys, indeed, only possess more water than our hills because the fall is so abundant as to gravitate from the higher ground to the lower.

The seasonal increase of definition of the lines downwards over the planet's surface, from the scene of the melting polar ice-cap, would naturally follow from this explanation. Quite recently M. Janssen has remarked, with regard to M. Perrotin's observation, that the canals are visible to a greater distance along a meridian than along a parallel, that this points to the presence of bodies which condense the water from the Martian atmosphere, and increase its transparency as the polar regions are approached. (*Nature*, February 25th, 1897.)

This explanation leaves the supposition that vegetation is concerned in the variable appearance of the canals as one which, although not necessary, is still not improbable. I may observe here that the argument for the presence of vegetation from the observation of bluish-green tints in the darker areas requires to be very carefully received, seeing that just such bluish-green tints would appear, as a physiological optical effect when dark areas on a brick-red background were under observation. If this red colour is deducted from our range of visible wave-lengths, the residium would give just such a bluish-green as Mr. Lowell depicts in his "Mars." Such residual sensation is that which the eye will perceive looking from the brighter red to the dark areas. This, however, will not explain the changes of tints observed by Lowell. Without having recourse to double or triple canals, we find, then, a reason for the varying conspicuousness of the lines in the natural conveyance of water by diffusion through the atmosphere, and its precipitation more abundantly as the supply of water increases with the advancing year. Slight atmospheric currents prevailing at particular seasons, as in the case of terrestrial atmospheric currents, will be sufficient reason for the erratic nature of the effects observed. To this may be added effects due to differences in the elevations of the low mountain ranges.

On the Curvature of the Lines.

It remains now to enter on the question of the amount of support which the foregoing views receive from an examination of the actual course of the lines as observed by Professor Schiaparelli and by Mr. Lowell and his colleagues.

If the foregoing views have any foundation in fact, the curvature of the lines, where this is sufficiently definite to admit of investigation, must be such as the composition of the motions of a uniformly rotating sphere and a point rotating uniformly round the centre of this sphere, will give rise to.

Certain conditions attending the composition of these motions are, in the first place, most probably prohibited from entering into the circumstances of the case under consideration. Mars' present rate of axial rotation cannot well be supposed to have been at any time *less* than its present rate. This excludes the great circle from being among the curves, for this curve, of course, corresponds to the particular case when the planet is at rest upon its axis, and the satellite rotating round it. If Mr. Lowell's contention that the curves mapped by him are indeed great circles is true, then the present hypothesis is hardly tenable. A very brief investigation suffices to show that the curves on Mr. Lowell's map where these curves are at all sufficiently prolonged to enable us to carry them, by safe exterpolation, to the equator, are not great circles. In the case of the great circle, the points of intersection with the equator must span 180°. This is, *at a glance*, evidently not the case with the greater number of his curves. The most careful examination of the others fails to reveal any curves satisfying this condition. A certain number of the curves rise from the equator along lines of longitude, apparently. It will presently be seen that this is no proof that they are parts of great circles. Meanwhile there is some *prima facie* evidence in the "rifts" observed by Mr. Lowell in the polar cap that the lines in question are not indeed great circles. It is reasonable to suppose that these rifts are the continuations of such lines. Now the definite rifts very plainly do not cross the pole, and therefore do not represent the continuation of lines following lines of longitude. Further than this, however, these polar rifts fail to enlighten us as to their course.

In addition to the great circle, curves, corresponding to axial rotations of the planet at a less velocity than the present, are, as already remarked, excluded. But general considerations attending the nature of the curves claim our attention before proceeding.

In Plate xv., a simple mode of plotting the intersection of the radius vector of a satellite with the surface of its planet is explained. We assume the satellite, supposed to be moving on the surface of the planet, to start at any instant from 0° longitude, and pursue the path inclined to the equator as marked out by the full straight line $0a$. This path is described in space by the satellite at uniform velocity. If the planet is supposed rotating in the direction of the arrow drawn upon the equator, this satellite is a *direct* satellite. Let the planet be turning at such an angular velocity that while the satellite accomplishes the distance $0a$ the point b upon the planet is transported the distance ba and so carried into the path of the satellite. The ratios of the angular distances $0a$ and ba represent the assumed ratios of the angular velocities of satellite and planet. Preserving this ratio, we similarly determine at sufficiently close degrees of latitude points which lie upon the curve. The curve formed by joining these points is that which this ratio of angular velocities gives rise to. It is seen dotted where it is carried round to its second intersection with the equator. The distance in degrees of longitude between these points of intersection we call the "span" of the curve.

It is apparent that this span at once determines the ratios of angular velocities of planet and satellite. In fact, as the remote point of intersection with the equator of the curve in question is that which will be carried under the path of the satellite when this has described 180° of its path, we may express the ratio of the angular velocities in terms of the span as follows:—

$$\frac{V_p}{V_s} = \frac{180 - \text{span}}{180}, \qquad (2)$$

where V_p and V_s are the angular velocities of planet and satellite.

In a similar manner it will be found that the ratio of the angular velocities in the case of a *retrograde* satellite may be expressed by:—

$$\frac{V_p}{V_s} = \frac{\text{span} - 180}{180}. \tag{3}$$

From these we see that the span due to a direct satellite cannot exceed 180° upon the equator, and that of a retrograde satellite cannot be less than 180°. The angular velocity of the satellite may be assumed invariable within the limits of distance at which it can effect the surface of the planet: any variations in the span of the curves must therefore be due to change in the rate of axial rotation of the planet. We have every reason to believe that this rate of axial rotation has continually been diminishing in the past, and hence expect to find such differences in the spans as the probable variations of the planet's velocity would account for, if at various periods in its history it picked up satellites.

To apply Mr. Lowell's map as a test of this hypothesis of the origin of the lines the mode of procedure will be readily understood (Plate XVI.).

We look preferably to the most complete and definite curves. The chains of canals of which Acheron and Erebus are members mark out such a fairly definite curve. We produce it by eye-judgment till it intersects the equator. Reading the span upon the equator, this is found to be 255°. In the first place, this curve is then due to a retrograde satellite. Inserting this number in (3), we find the ratio of the angular velocities to have been as 5 to 12. The point of highest latitude of the curve gives the inclination of the satellites' orbit to the equator. These data enable the curve to be constructed upon the sphere as before. Transferring this to a Mercator's projection on the same scale as Mr. Lowell's map of Mars, it is possible to apply a tracing of the curve to Lowell's map, and examine the degree of similarity between the curves.

In this process we are assuming three points from Lowell's curve, and plotting a curve according to a particular law to pass through these three points. This law involves the hypothesis under consideration in this Paper. It is, of course, possible to draw an indefinite number of curves through three assigned points. But we find, as will be seen from the reproduction of Mr. Lowell's map in Plate XVI., that the curve just determined, which is drawn as a dotted line, coincides closely with that observed by Mr. Lowell and his colleagues. Transferring our attention from one to another of the dotted curves drawn upon Lowell's map, it will be seen that, in nearly all the cases dealt with—and the principal definite curves have been examined—*the curve, determined according to the present hypothesis, lies closely along or upon the observed curve.* I venture to think this agreement cannot be accidental.

The curves upon Lowell's map, which nearly lie along meridian lines, are, it will be observed, accounted for on the supposition that these lines if pursued further towards the poles would be found to be curved out of the meridional direction, and so would cross the poles in the manner in which the rifts cross the polar cap in Lowell's map, showing the progressive melting of this cap ("Mars," plate ii., p. 84). These lines will also be found plotted upon the sphere in Plate xv. They correspond to the path of a satellite rotating at a very high angle to the equator. Upon Plate xv. will also be found projections on the sphere of many of the lines plotted upon the Mercator's projection of Plate xvi. In the projections the retrograde curves are distinguished by a minus sign, as the character of the curve is not in all cases apparent from inspection.

To consider each curve inscribed according to the present hypothesis upon Plate xvi. would be needless. The agreement is apparent even to casual inspection. In a couple of cases it will be perceived that I have assumed a curve to be compound in nature. One instance is that of the chain of Boreas and Anapus. The latter I have assumed to form part of a curve drawn to the approximate velocity ratio of 4 : 9. The former I have suggested to represent a very early impression upon the planet's crust. The equality ratio 1 : 1 will account for such a slightly curved line. But in such a case it is perhaps better to refer the curve to better observations than we at present possess, remarking that the curve is a possible curve even as it stands. It appears permissible to assume that the one other case (Erannoboas and Cephissus) is referable to the canals meeting by chance only.

The following conditions and attributes of these curves will serve to complete the present reference to them.

A satellite rotating at a distance of 60 miles from the surface of Mars will complete its month in one hour and forty minutes. At the present rate of axial rotation of Mars this involves a ratio of 1 : 13. From this it follows, assuming that Mars can never in the past have been rotating at a slower rate than at present, that spans possessing values between 166° and 194° are inadmissible.

A direct span greater than 180° involves that the planet revolved faster than the satellite; a retrograde span greater than 360° also involves this assumption; which may be considered precluded on dynamical grounds.

At any particular ratio of velocities an indefinite number of curves are possible, according to inclination of orbit of the satellite, but only two spans can obtain, the direct and the retrograde.

The closed curve is not necessarily that which might be marked out by a satellite. If the ratio of velocities is not represented by whole numbers, the satellite will describe a curve which does not enter into itself. The number of revolutions or months determining the repetition of the curve, in the case when the curve is a closed one, will depend upon the ratio of velocities. In certain cases very many curves circling the planet are struck, as in the manner of the composition of simple harmonic motions—to which these curves are analogous—before the figure repeats itself.

The several loops may or may not intersect upon the equator or off the equator according to the nature of the ratio of velocities determining the curve.

If planet and satellite rotate at like angular velocities the retrograde curve will intersect upon the equator at one point, the span being 360°. If the curve is direct, it crosses the equator at one point with a span of 0°. In certain cases, as for example such a ratio as 1 : 8, the number of crossing points in each hemisphere is very considerable in each complete description of the curve.

In the consideration as to the agreement of the curves with the theory that these originated in the near approach of satellites, I have confined myself to the map of Mr. Lowell. That Schiaparelli's maps agree with Lowell's, in so far as these overlap, is obvious on inspection. But the lines on Schiaparelli's map are less definite, and differences exist between his earlier and later maps. I therefore considered the more definite map of Lowell most suitable to this investigation, as serving to apply, in fact, a more rigorous test to the hypothesis. Both observers ascribe the same general character to the curves, in that they are shown to be concave and generally symmetrical to the equator.

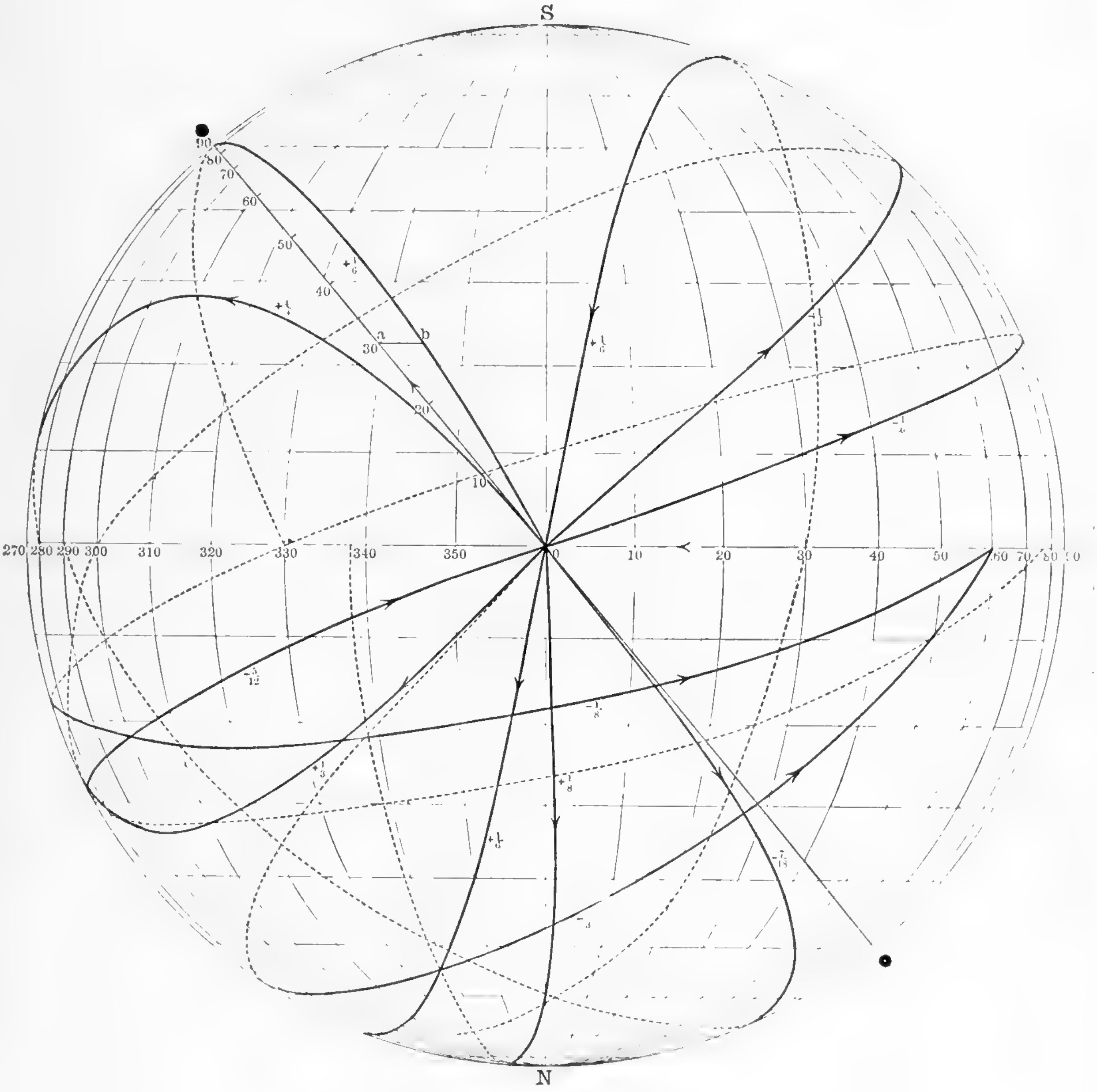
The Radiants.

No hypothesis as to the origin of the lines on Mars will be complete without extending to the disposition of these lines as in some cases radiating from certain centres. The crossing of the several loops of the curves will hardly account, without some auxiliary supposition, for the appearance presented by such a radiant as the Sinus Titanum, for example.

It appears to me that the explanation of these radiants is indeed not to be looked for in this direction, but to be found in the effects of perturbations upon small satellites by raised surface features on Mars. This is only offered here as a suggestion, for without more complete investigation and possibly without more knowledge than we at present possess, the effects and possibility of such perturbations must be pure guesswork. But in support of this suggestion it is to be observed that the radiants of pronounced character are situated upon the coast lines or at the larger oases or spots. The latter, according to the views in this Paper, are raised features, and raised features on the coast lines are in keeping with terrestrial physiography. Indeed dark triangular marks characterise these coast-line radiants.

I assume that raised features may effect the path of a satellite both in swaying its orbit to some extent, and also in drawing it down nearer to the surface of the planet. The latter effect will result in the orbit departing further from the surface at other points. These may indeed be but very gradual and very slight effects. But very gradual and slight effects favouring one direction more than another, that is, favouring continuance of the satellite, or its approximation to the surface, along this direction, will be effective if they suffice to distinguish this direction from among, probably, innumerable directions in which satellites have left a record of their presence. "What their number may be lies quite beyond the possibility of count at present; for the better our own air, the more of them are visible." So writes Mr. Lowell of the actual number of lines visible on the Martian disk. ("Mars," p. 135.) What we see then are the incomplete fragments of curves and the survival of the fittest. Any cause favouring one direction, serving to intensify the physical effects of a satellite rotating in or near this direction, may be held conducive to this survival. If we suppose, now, that such a line as the Eumenides-Orcus is formed as a line of disturbance in the first instance, and the oases formed by the crossing of secondary lines, such a manifold radiant as the Sinus Titanum would arise as the result of directions which favoured the approach or retention of a satellite or satellites; directions taking in the raised masses of the oases, and the coast-line elevations. An appearance resembling the tying of triangles in survey triangulation would thereby be produced. Future observations as to the actual nature of the oases and the coast features will throw light on this matter. Consideration of the dynamical questions involved will be not less important.

It only remains for me to express the hope that others able to enter more fully on the many difficult matters touched upon in the course of this Paper will not deem the question unworthy of attention. The prize is great. Should these suggestions prove to have a foundation in fact, the face of Mars will have proved a very Principia; an open book on which is written not only confirmation of views on the physics of a planet's crust which as yet must rank as speculative geology only, but also experimental illustration of far reaching deductions from lunar theory.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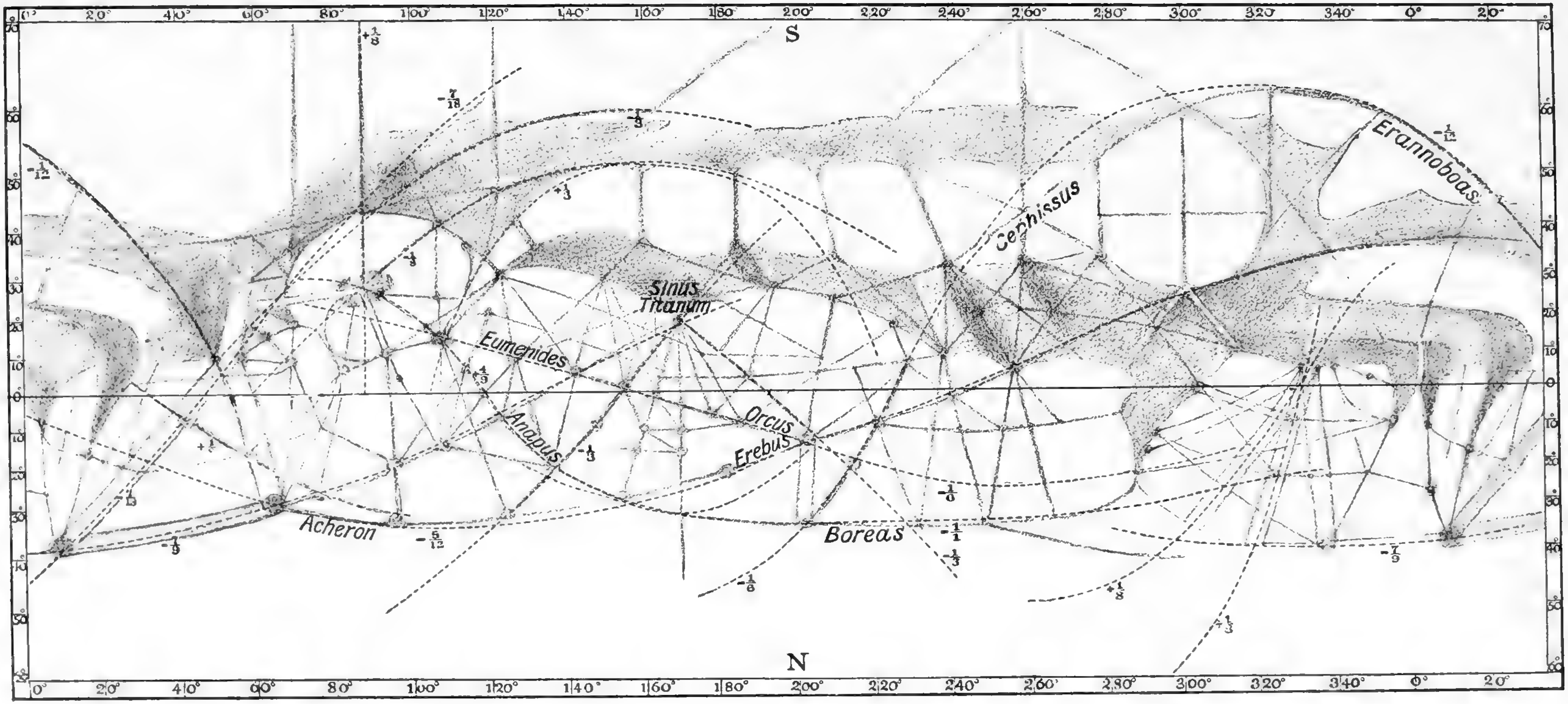

Map of Mars on Mercator's Projection.

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[Read APRIL 21, 1897.]

INTRODUCTION.

IN this continuation of my studies of the changes in composition of dissolved gases which accompany bacterial fermentations in waters, I propose to detail and discuss some experiments with certain organic substances which belong to the class termed in my previous communication, difficultly fermentable substances, to distinguish them from the class of substances which readily undergo fermentation in the presence of the micro-organisms ordinarily present in air and water, to which class most of the remaining known organic substances, with the exception of antiseptics, probably belong.*

The organic substances which may be included under the heading of "difficultly fermentable" are those found in good natural waters, and also those to be found in sewage, or other polluted waters, that have been subjected to complete fermentation under aërobic conditions, such as obtain during slow filtration through sand and soil.

I have already dealt with some of the latter forms of organic substances,† and also with some forms to be met with in natural waters, viz. peaty colouring matters.‡

The substances which have been employed for the experiments that I have presently to describe may be regarded as representative of the organic matters which occur in cultivated soils, and which find their way more particularly into well and spring waters.

Before proceeding, however, to the consideration of fresh experiments, it is

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* Trans. Roy. Dub. Soc. N.S., Vol. v., Part xi., p. 540, 1895.

† *Loc. cit.*, Tables V., IX., X., etc.

‡ *Loc. cit.*, Tables XIV., XV., and XVI.

desirable to decide upon the use of two new terms to indicate the two stages by which organic substances successively suffer aërobic fermentative change in waters, as described in my previous communications. During the first, an organic substance in solution is completely broken up; much the greater part of its carbon—about 90 per cent. in some cases*—is converted into carbon dioxide, and almost all its nitrogen into ammonia (with the one exception of *pure* urea, the nitrogen of which is partly changed into ammonia and partly into *nitrous* acid†). A small quantity only of organic matter remains after the completion of this stage, and that in a very much altered form.

The characteristic feature of the second stage of change is the oxidation of the ammonia, which may have been formed during the first stage, or which may have been originally present in the form of an ammonium compound, to nitrous and nitric acids.

The organic matters resulting from the first stage of change also suffer a more or less complete oxidation in company with the ammonia during this second stage, and appear to play the important part of determining the final oxidation of the ammonia to *nitric acid*,‡ since when they are entirely absent—a fact now well known—the product of oxidation is *nitrous acid only*.§

These organic matters also undergo a second stage of change *in the absence of ammonium compounds*; under these conditions, however, the change takes place extremely slowly; the products of the change are carbon dioxide and nitric acid.‖

It is important to note, in reference to these organic products of a first stage fermentative change, or, as we may call them, fermented organic matters, that, whatever changes they undergo, *they never give rise to the formation of ammonia.*

It has been suggested to me to employ the terms bacteriolysis or aërobiolysis for the first stage, and to restrict the use of the term nitrification to the second stage, of change. The restriction of the term nitrification to the use in this sense is, I think, most advisable, and I propose to employ it only in this sense in this and in future Papers.

It would also be convenient to adopt a simple word, such as bacteriolysis or aërobiolysis for the first stage of change; but, as my friend Professor W. N. Hartley, F.R.S., has pointed out to me, neither of these terms can be regarded as indicating with sufficient accuracy the true nature of the chemical changes which take place during its course. He has suggested that the terms carbon-oxidation

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* *Loc. cit.*, Tables VII., VIII., XI., and XII.

† *Loc. cit.*, Table XVII.

‡ *Loc. cit.*, Tables III., V., VII., VIII., X., XIII., XV., and pages 587, 588.

§ *Loc. cit.*, Table XVI.

‖ *Loc. cit.*, Table XIV.

and nitrogen-oxidation more accurately describe the two stages of change, on the grounds that the phenomena dealt with in these studies are really processes of decay or eremacausis, and that it is important that it should be clearly shown that no such change can take place in organic matters without heat evolution, whether brought about by the action of organisms, or by the action of fire; that is to say, actual combustion.

The terms suggested by Professor Hartley have the great advantage of accuracy in their application, and, as a matter of fact, I occasionally used the terms carbon-fermentation and nitrogen-fermentation in a similar sense in my first Paper,* but hesitated to propose their general adoption, hoping that less cumbersome terms would suggest themselves after the publication of the Paper. In the absence, however, of such suggestion, I now propose to adopt the terms carbon-oxidation, and nitrogen-oxidation, or nitrification, to respectively denote the first and second stages of aërobic fermentative changes which form the subject of these studies. With the adoption of these terms, we may also adopt the classification of all fermentable bodies into (1) carbon-oxidizable bodies, or all fermentable organic substances which have not undergone carbon-oxidation; and (2) nitrifiable bodies, or ammonium compounds, and organic bodies which have suffered carbon-oxidation.

OBJECT OF EXPERIMENTS.

Turning now to the consideration of the experiments which I have to describe and discuss in this Paper—they have been made with the view of supplementing the information which I have already published upon the fermentative, and certain other, properties of the nitrifiable organic substances to be met with in natural waters.

These substances may be divided into three classes, according to their origin: viz. (1) the organic matters derived from the carbon-oxidation of fermentative organic substances in solution, *e.g.* those present in most good river-waters; (2) those derived from peat, *e.g.* those to be found in upland surface-waters; and (3) those derived from the organic matters or humus in soil, *e.g.* those found in spring and well waters.

Classes 1 and 2 have been dealt with in Parts I. and II. of my first communication. I have now to take up the consideration of class 3, and I may add that, fortunately for my purpose, I have been able to employ a specimen of humus, the formation of which I knew beyond doubt to have been due to a true carbon-oxidation of fresh animal and vegetable solid refuse matters kept in a moist condition.

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* *Loc. cit.*, p. 610.

ORIGIN OF THE ORGANIC MATTERS (HUMUS) EXPERIMENTED WITH.

I have already made some reference to this humus in a short Paper published in the "Scientific Proceedings" of this Society.[*] It was found in some sewage sludge which had been allowed to ferment for some time under what were practically aërobic conditions. The sludge had been obtained from a sewage purification works, in which the coarser portion of the solid matters in suspension in the sewage were first separated by mechanical subsidence; the sewage was then mixed with a water solution of manganate of soda; the peroxide, which separated out, was allowed to subside, together with the matters remaining in suspension in the sewage, to the bottom of the tank in which the operation was conducted. It was finally drawn off from the tank in the form of a mud. I obtained several hundredweights of this mud, and first drained it on a gravel bed, and, when of sufficient consistence, I made it up into a large heap, and allowed it to slowly air-dry in a covered shed. After being left in this condition for about three months, I found the interior portions had assumed a grey colour, and were still wet and clay-like in consistence; only those portions of the heap immediately exposed to the air had retained the original brown colour of the peroxide.

Some small lumps were detached from different parts of the interior of the heap, and allowed to completely air-dry; an average portion was then analysed. The results of the analyses are given in the Paper above referred to (p. 250), and it will only be necessary to quote here the main results. They are:—

	Percentage.
Insoluble mineral matter and silica,	16·66.
Moisture,	15·68.
Organic matter, "soluble in HCl,"	4·35.
,, "insoluble in HCl,"	4·00.
MnO,	24·60.
$(NH_4)_2O$,[†]	0·005.
CaO, Fe_2O_3, Al_2O_3, MgO, Na_2O, K_2O, NiO, CoO, ZnO,	15·46.
CO_2,	18·98.
'SO_3, 'P_2O_5, 'Cl,	0·96.
	100·695.

The above results show that the manganese was present as manganous carbonate: a careful examination was made for peroxide, but with negative results.

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[*] "On the Reduction of Manganese Peroxide in Sewage," vol. VIII., N.S. (1894), p. 247

[†] The NH_3 in the wet mass, before complete air-drying, amounted to 0·014 per cent. (calculated on the wet mass which contained about 60 per cent. moisture).

No trace of sulphuretted hydrogen, nor of other products of putrefactive fermentation, such as are met with when sewage solid matters alone are kept under similar conditions, were detected. An examination for nitrates was also attended with negative results.

Freshly precipitated manganese peroxide is also rapidly reduced to manganous carbonate when it is kept immersed in comparatively large volumes of sewage water, in which bacterial fermentation is actively proceeding.

REDUCTION OF HYDRATED MANGANESE PEROXIDE IN THE PRESENCE OF ORGANIC MATTER DUE TO LIVING ORGANISMS.

I pointed out, in the Paper above referred to, that, when we consider the chemical characters of the peroxide of manganese, it seems impossible to avoid the conclusion that it owed its reduction to manganous carbonate, to the influence of some, at least, of the organisms which were abundantly present in the liquid with which it was saturated or immersed, and that the decomposition was analogous in character to that which Gayar and Dupetit* have shown nitre undergoes when it is present in a nutrient medium in which certain organisms are grown; and I showed, by means of thermo-chemical equations, that if the decomposition of the peroxide of manganese be thus regarded as the result of a fermentation, consisting of the direct oxidation of organic carbon at the expense of its available oxygen, the changes would be attended with considerable heat evolution, and would therefore constitute a considerable source of energy to the organisms.

We may now, however, take it for granted that the reduction of the moist peroxide, in the presence of organic matters, is the work of living organisms; for since the publication of my Paper referred to, my friend and colleague, Dr. E. J. McWeeney, has made the question a subject of bacteriological examination, and he has informed me that, in his experiments, in which he kept freshly precipitated manganese peroxide in carefully sterilized nutrient liquid media, no reduction of the peroxide was noticed, but that, in those experiments in which the nutrient media were seeded, after sterilization, with particles of the same fermented sludge as that with which I had worked, a rapid and very abundant growth and development of living organisms took place in the media; and at the same time it was noticed that the brown colour of the peroxide immersed therein was gradually and completely changed into a yellowish white. I subsequently examined this white substance myself, and found it to consist of manganous carbonate. I should add that the nutrient medium employed by Dr. McWeeney was a mixture of asparagine

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* "Ann. de la Science Agronomique," 1885, I., 226; also abstract "Chem. Soc. Journ.," XLIX., p. 823.

and rochelle salt, dissolved in distilled water, to which was added a little sodium phosphate and potassium chloride.

We may therefore regard the chemical changes which took place in the mixed solid sewage organic matters and peroxide of manganese, in the mass above described, as a true carbon-oxidation of the organic matters, the available oxygen of the peroxide affording the necessary supply of that gas to the living organisms, just as the dissolved atmospheric oxygen did in the solutions of the organic matter with which I carried out my experiments on carbon-oxidation of *soluble* organic matters.*

I propose to give an experimental proof that the organic matters which resulted from this process of carbon-oxidation possess all the fermentative, besides the physical and chemical, properties which I have already shown fermented organic matters and peaty colouring to possess in common.

DESCRIPTION OF EXPERIMENTS UPON THE FERMENTATION OF THE HUMUS.

As will be gathered from the above Table of Analysis, a portion of the organic matters present in the sludge was taken up by the acid employed for dissolving out the soluble portions of the substance. Practically, however, all was left undissolved when the solution was evaporated to dryness, and the residue treated with hydrochloric acid, in the ordinary way, for the separation of silica if present.

The organic matters which were separated in this way were employed for the experiments I have to detail. They were brownish black in colour, and were slowly but completely soluble in a solution of sodium carbonate. The solution obtained was of a deep brown colour, indistinguishable from an extract of peat or of garden soil similarly prepared. The ratio of organic carbon to nitrogen was 6·84 : 1. They were therefore similar in these particulars to the organic matters contained in the extract of peat employed for the experiments recorded in Part II. of my first Paper.†

I should add that the portions of the sludge which were undissolved by hydrochloric acid, also yielded, on treatment with sodium carbonate solution, a deep brown solution. The details of experiments with this portion of the organic matters of the sludge I must, however, leave to a future Paper, should they prove

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* Professor W. N. Hartley, F.R.S., has recently published a short interesting paper on "The Cause and Nature of the Chemical Changes occurring in Oceanic Deposits," in which he points out that the chemical changes which take place between the organic matter and the mineral salts in fresh- and sea-water mud are to be ascribed to the action of well recognized living organisms, and shows, by thermo-chemical equations, that, at each stage of change, there is heat evolution.—Proc. R. S., Edinburgh, 1895–96, p. 25.

† *Loc. cit.*, p. 593.

to differ in fermentative properties, which, however, I do not anticipate. The ratio of organic carbon to nitrogen of the total organic matters in the fermented sludge was 7 : 1.*

The experiments with the organic matters above described were carried out in accordance with the methods described in my first Paper. The analytical determinations, made before and after keeping the various solutions, employed for experiment, out of contact with air, are recorded in the following Table XVIII.

The first solution (*H*) was prepared by dissolving a known weight of the humus in distilled water and a little sodium carbonate; and when the solution was complete, a few drops of sediment from one of my old experiments with peat extract were added for the purpose of seeding, together with the necessary mineral salts, and the whole was diluted to the necessary bulk with distilled water.

The solution *H′* contained a similar quantity of humus in solution as *H*, but more sodium carbonate, and, in addition, ammonium chloride.

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* It should also be noted that an examination of wet portions of the fermented sludge was made at the time the above analysis was carried out, with the view of ascertaining whether there still remained in the sludge any organic matters which had not undergone complete carbon-oxidation. For this purpose, about 40 grms. of the sludge were saturated with 2 litres of water; and portions of the water, with the sludge matters in suspension, were transferred to bottles and preserved out of contact with the air for 21 days, according to the method I have described. On examination of samples (in which, of course, the matters in suspension had previously been allowed to completely subside), before and after keeping, indications of a considerable fermentative change were found. The whole of the dissolved oxygen had been consumed during the period of keeping out contact with air, and a large volume of carbon dioxide formed; but inasmuch as no appreciable increase in the amount of ammonia, originally present, was detected, and the water remained perfectly free from unpleasant odour, or any other indication of putrefactive fermentation. It appeared evident that the fermented sludge, at the time I commenced my examination of it, contained only small quantities of organic matters that had not undergone complete carbon-oxidation. No nitrous nor nitric acid was detected in these solutions, either before or after keeping.

TABLE XVIII.—*Experiments with Humus obtained by the fermentation of wet solid animal and vegetable matters in the presence of hydrated manganese peroxide.*

Solution H contained 0·0465 grams organic carbon,
0·0068 ,, ,, nitrogen,
0·1 ,, Na_2HPO_4,
0·1 ,, KCl,
a small quantity of $NaHCO_3$, } per litre.

[The gases are expressed in c.cs., measured at 0° C., and 760 mm. bar., the other constituents as parts by weight, per litre of water.]

No. of experiment.	Date of commencement and of conclusion of experiment.	Description of Experiment.	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5	Remarks.
1	Feb. 24, 1896,	Solution H, aërated, . . .	16·73	7·52	15·30	·0002	0	0	Deep brown colour.
	Mar. 17, ,,	Same after fermentation, . . .	17·80	5·29	15·35	·0002	0	·0002	Ditto.
1*a*	July 20, ,,	Another bottled portion after fermentation,	19·84	2·09	15·26	0	0	·0006	Ditto.
2	Feb. 24, ,,	Solution H + AmCl = H_1, . . .	16·73	7·52	15·30	·004	0	0	
	Mar. 2, ,,	Same after fermentation, . . .	17·23	6·52	15·2	·004	0	0 ?	
2*a*	,, 30, ,,	Another bottled portion after fermentation,	18·19	4·81	15·33	·004	0	·0002 ?	
3	,, 16, ,,	Solution H_1 diluted with distilled water, 1 : 9,	7·08	7·66	15·2	·0005	0	·0008	Faintly but distinctly coloured greenish yellow.
	Mar. 24, 1897,	Same after fermentation, . . .	8·97	3·51	15·0	0	0	·001	Ditto.
3*a*	,, 25, ,,	Another bottled portion, . . .	8·51	3·66	15·08	0	0	·001	Ditto.
4	Mar. 31, 1896,	Remaining solution from Exp. 1 and 1*a* + more solution (H′) of Humus + AmCl (prepared Feb. 26); whole diluted with equal bulk of water = H_2,	24·09	7·77	15·48	·0024	0	·0004	Strongly coloured brown.
	July 21, ,,	Same after fermentation, . . .	26·49	0	15·34	·0001	·00112	·00078	Ditto.
4*a*	,, 23, ,,	Another bottled portion after fermentation,	26·22	0	15·39	·00005	·00144	·00091	Ditto.
5	April 4, ,,	Solution H_2 + AmCl, diluted with distilled water 1 : 6,	7·78	7·59	15·30	·0016	0	·0002	Faintly but distinctly coloured yellowish brown.
	July 25, ,,	Same after fermentation, . . .	7·72	1·16	15·13	0	0	·0018	Ditto.
5*a*	Jan. 5, 1897,	Another bottled portion after fermentation,	7·65	0·98	15·16	0	0	·00195	Ditto.

The results of the experiments recorded in the previous Table will be more readily seen when expressed in a tabular form as follows :—

TABLE XIX.—*Showing quantitatively the fermentative changes which occurred in the composition of the dissolved gases, and of the inorganic nitrogen compounds during the experiments recorded in the previous Table.*

No. of Experiment.	Duration of Experiment.	CO_2	O_2	N as NH_3	N as N_2O_3	N as N_2O_5
1	22 days, . .	+ 1·07	– 2·23	—	—	+ ·0002
1*a*	5 months. . .	+ 3·11	– 5·43	– ·0002	—	+ ·0004
2	7 days, . .	+ 0·50	– 1·00	—	—	+ 0 ?
2*a*	35 days, . .	+ 1·46	– 2·71	—	—	+ ·0002 ?
3	1 year, . .	+ 1·89	– 4·15	– ·0005	—	+ ·0002
3*a*	1 year, . .	+ 1·43	– 4·00	– ·0005	—	+ ·0002
4	4 months, . .	+ 2·40	– 7·77	– ·0023	+ ·00112	+ ·0007
4*a*	4 months, . .	+ 2·13	– 7·77	– ·00235	+ ·00144	+ ·00087
5	4 months (nearly),	– 0·06	– 6·43	– ·0016	—	+ ·0016
5*a*	9 months, . .	– 0·13	– 6·61	– ·0016	—	+ ·00175

On examining the results recorded in the above Table it at once becomes apparent that the fermentative properties of the humus employed for the experiments are alike in character to those which I showed in my first communication were so characteristic of fermented organic matters and of peaty colouring matters, and to which I have already referred.

For example, in experiments 1 and 1*a*, in which the humus was present in comparatively large, and the ammonia in extremely small, quantity, we have a very slow fermentation, the products of which are carbon dioxide and nitric acid, which was partly derived from the nitrogen of the humus.

In experiments 2 and 2*a*, it is evident that the time allowed for fermentation was insufficient, and only a slight fermentative change is exhibited, resulting simply in the production of small volumes of carbon dioxide, the consumption of small volumes of oxygen, and the doubtful formation of a small quantity of nitric acid. In the succeeding experiments 3 and 3*a*, a part of the same solution as that employed for experiments 2 and 2*a*, and which was kept in a vessel freely exposed to the air between the dates February 24th and March 16th, was diluted, on date of experiment, with distilled water in the proportion of one volume of the former to nine of the latter, and used. The results were the formation of small quantities of carbon dioxide, and of nitric acid, the consumption of a part only of the dissolved oxygen, and the disappearance of all the ammonia originally present.

In experiments 4 and 4*a*, it became necessary to employ, in addition to the portions of *H* which remained from previous experiments, some fresh solution of humus (*H′*), which had been prepared on February 26th previously, and had been kept since its preparation in a vessel freely exposed to the air. These experiments were made to examine the fermentative properties of the humus in the presence of a decided quantity of ammonia under more suitable conditions than experiments 2 and 2*a* were found to afford. In those experiments, the ammonia was present in unnecessarily large quantity, and prevented the certain detection of small quantities of nitric acid if formed. Accordingly, for experiments 4 and 4*a*, a less quantity of ammonia was taken, and a longer time allowed for fermentation. The results of these experiments showed that, when the dissolved oxygen was insufficient for the complete oxidation of the ammonia present, both nitrous and nitric acids may be formed, and small volumes also of carbon dioxide.

The conditions secured for the next and final experiments (5 and 5*a*) were arranged, so that oxygen should be present in just sufficient quantity for the complete oxidation of the ammonia, and in each experiment the oxidation of the ammonia to *nitric* acid was complete. These experiments also prove that a *nitric* fermentation of ammonia may be carried on in the presence of small quantities of humus, without any carbon dioxide being formed, there being some evidence (see 5*a* more especially) that a small quantity of carbon dioxide was actually "fixed." Abundance of evidence of a similar *nitric* fermentation, in the presence of both fermented organic matters and of peaty colouring matters, will be found throughout my first communication.

These experiments afford additional evidence, to that I have already published, to the effect that organic matters, which are themselves the result of bacterial fermentative changes, or a carbon-oxidation of fresh organic substances, take an active part in any subsequent fermentation of ammonium compounds with which they may be mixed, and determine the *nitric* fermentation of those compounds.*

In addition they extend our knowledge of nitrifiable organic substances to those which may be derived from cultivated soils, or, in other words, to the organic matters which may be more especially met with in waters that have passed through cultivated soils (spring and well waters); and they show that these organic matters in no way differ in general fermentative properties from those to be met with in waters holding peaty colouring matters in solution (upland

* *Loc cit.*, pp. 593–613.

surface waters), or from those to be met with in waters in which a complete carbon oxidation of the organic matters from past pollution by sewage, or other surface drainage waters, has taken place (most, if not all, good river-waters).

We have, in fact, from these experiments, and those I have already published, fairly complete information as to the possible fermentative changes which the nitrifiable substances to be met with in natural waters, whethe they be upland surface, well or spring, or river waters, may undergo.

These changes may be briefly summarized as follows:—

1. When the nitrifiable substances are freshly formed, and are present in comparatively large quantity in a water, the formation of a decided volume of carbon dioxide, in proportion to the volume of dissolved oxygen consumed, and the formation also of a quantity of nitrous or of nitric acid, or both, but in small quantities, may attend the earliest stage of fermentative change they may undergo.*

2. At subsequent stages the volume of carbon dioxide formed is not so large, and the inorganic nitrogen products, nitrous or nitric acid, become the more marked in quantity in proportion to the oxygen consumed.†

3. At a still later stage, at the completion of which all the ammonia becomes fermented, little or no carbon dioxide may be found, but, on the contrary, a little may become "fixed"; the inorganic nitrogen products consists then of nitric acid solely.‡

4. When little or no ammonia is present, *freshly* formed nitrifiable organic matters may undergo at first a slow change, during the first steps of which distinct volumes of carbon dioxide and of dissolved oxygen may be formed and consumed, respectively; small quantities of nitric acid are formed at the same time.§

5. But after these earlier steps of change the fermentation becomes slower, and finally becomes so slow as to be scarcely appreciable; still the results are the formation of carbon dioxide and nitric acid, and the consumption of a proportionately small volume of dissolved oxygen.||

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* *Loc. cit.*, Table V., exp. 1.; Table XIV., exp. 2; Table XV., exps. 1*a* and 1*b*.

† *Loc. cit.*, Table V., exp. 3; Table VIII.; Table XIII., exp. 7; Table XV., exps. 3, 4, 5, 2*a* and 3*a*; also Table XVIII. (above) exps. 4 and 4*a*.

‡ *Loc. cit.*, Table V., exp. 4; Table VII., exp. 6; Table X., exp. 3; Table XV., exp. 2*b*; also Table on p. 588; also Table XVIII. (above), exps. 5 and 5*a*.

§ *Loc. cit.*, Table XIV., exp. 5.

|| *Loc. cit.*, p. 561; Table IX., exp. 4; Table XIII., exps. 5 and 6; Table XIV., exp. 6; also Table XVIII. (above), exps. 1 and 1*a*, and 3 and 3*a*.

This brief summary of the fermentative changes which nitrifiable organic substances may undergo in the presence and absence of ammonia shows how definitely and easily this class of inorganic substances may be differentiated from unfermented or "carbon oxidizable" substances when both classes occur together in a water; and it emphasizes the point I put forward in Part III. of my first communication, viz. that the analysis of suspicious and polluted waters should always include an examination of the fermentative changes which may occur in the composition of the dissolved gases and of the inorganic nitrogen compounds contained in such waters—an examination which is easily made, when the waters are preserved in the manner and under the conditions I have described.

If, for example, a water be regarded as suspicious for potable purposes, on account either of its containing too much organic matter, or an abnormally large amount of ammonia, an examination of it by the methods I have employed in these studies will yield exact information, whether, in the first case, any portion of the organic matters are in an unfermented condition or not, and, in the second, whether the ammonia will suffer rapid nitrification or not.

Information as to both these points are essential before a definite opinion can be expressed as to the suitability or otherwise of the water for potable purposes. Since a positive result in either case would definitely condemn the water for such use, for, in the first case, very recent pollution would be indicated, while in the second case an abnormal bacterial activity would be revealed, which, in the light of recent bacteriological teachings as to the true functions of a filter, ought to be regarded as indicating insufficient filtration. As an example of this latter case, I may quote the examination of a water which recently came under my notice. An ordinary analysis showed that the water contained ammonia in somewhat excessive quantity, viz. ·016 parts (nitrogen as ammonia) per 100,000 of the water. It also yielded ·009 nitrogen as albuminoid ammonia per 100,000. The water was classed as suspicious, and I examined it for fermentative changes with the following results:—

	CO_2	O_2	N_2	N as NH_3	N as N_2O_3	N as N_2O_5
Before keeping, . . .	113·69	4·03	15·69	·00016	0	·0025.
After keeping for 7 days, .	113·59	3·76	15·76	0	0	·0025.
Fermentative changes, .	—	−0·33	—	−·00016	—	—

The constituents are expressed as in the previous Tables, viz. gases as c.c. at N. T. P., and nitrogen compounds as parts by weight, per 1000 c.cs. of water. It should be noted the water was slightly turbid, but contained no suspended matter. The results show the ammonia was completely taken up, and that a corresponding volume of oxygen was consumed during the seven days the water was kept, but that no carbon dioxide was formed. This comparatively rapid nitrification of the ammonia must have been due to a decided bacterial activity in the water. On subsequent inquiry it was found that cases of typhoid fever had occurred in the house supplied from the well.

When we turn to the consideration of polluted waters in reference to the question of the pollution of rivers, I think it will be conceded that the experiments recorded in this, and in my previous Papers, establish beyond question the desirability and necessity of including, in the analysis of such waters, a determination of the unfermented organic matters they may contain, in terms of the volumes of free oxygen and of carbon dioxide which will be consumed and formed, respectively, and also if they contain nitrogen of the ammonia which will be formed during their complete carbon-oxidation.

To complete the analysis of such waters, the volume of free oxygen consumed during the subsequent nitrification of the ammonia may be determined, but this, I believe, will be found unnecessary for technical purposes.

I trust shortly to be able to publish the results of some further experiments both in carbon-oxidation and in nitrification, the solutions for which have been preserved at blood-temperature in an incubator.

TRANSACTIONS (SERIES II.).

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[October, 1897.]

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XII.

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By J. JOLY, M.A., B.A.I., Sc.D., F.R.S., Hon. Sec. Royal Dublin Society.

(Plates XVII. and XVIII.)

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ON THE VOLUME CHANGE OF ROCKS AND MINERALS ATTENDING FUSION.

By J. JOLY, M.A., B.A.I., Sc.D., F.R.S., Hon. Sec. Royal Dublin Society.

(Plates XVII. and XVIII.)

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ON THE VOLUME CHANGE OF ROCKS AND MINERALS ATTENDING FUSION.

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[Read May 19, 1897.]

It is now some years since I exhibited before the Royal Society of London the method and experiments described in the following pages:—The exhibition finds record only in the Catalogue of the Exhibits (June, 1892), the mode of experimenting finds but a scant explanation, and the results are necessarily not recorded at all. Later (*Nature*, March 22, 1894), a short account of the method in connexion with its application to determining the thermal expansion of diamond appeared.

The experiments were thus held over in the hopes that leisure would be found to extend them. But as the value of the method as affording closely approximate results is, I venture to think, beyond doubt, and as it may still be long before the opportunity to extend the results arises, I have thought it best to give here an account of the work already accomplished. The question whether the volume change upon fusion of certain important rocks is positive or negative in character finds an undoubted answer in the results here recorded. This answer is not of the less value because it confirms the results of other observers. The method avoids sources of error to which older methods are open. But not only is this important question answered definitely, but also the course of the volume change from air temperatures up to those above softening is indicated. There is also the added reason for the publication of the method that others may possibly avail themselves of it, seeing that it is applicable generally to the problem of determining the volume-change of minute quantities of a substance over high ranges of temperature.

The method is very simple. The small fragment of the substance to be dealt with is placed in the field of a microscope, and an image of the fragment projected into a photographic camera, where it appears upon the focussing screen magnified about 80 or 90 diameters. This image is observed at opposite points by two micrometer microscopes, so that opposite edges of the image may, upon any enlargement of the object, be kept upon the movable spider-lines of the micrometers, and the amount of enlargement measured over extreme changes of temperature. Or a photograph may be taken both when the substance is cold and when it is heated, and the amount of expansion of the image may be measured upon the photographs.

To effect the heating of the substance while thus maintained in the field of the microscope might appear to present great difficulties. The difficulties were surmounted by the use of an oven consisting of a ribbon of platinum which could be heated to any required temperature by passing a current through it, and which was folded in such a manner round the substance that this occupied the centre of a heated tube, of considerable length relatively to the dimensions of the substance, and so placed that the light employed to illuminate the object entered at one end of the tube while the rays going to the lens emerged at the other. The observer thus looks axially into the tube. The axis of the tube was maintained horizontal, the microscope serving to project the image into the camera also being in a horizontal position.

Before entering into details a few numbers showing the attainable degree of accuracy will be of interest.

The case of observations on the expansion of diamond, in which the magnification was by no means so high as was in some cases found practicable, will show the magnitudes dealt with. The diamond in question was rather less than 2 millimetres in diameter, that is as measured from one extreme solid angle of the octahedron to the other. It was so supported in the field of the microscope that two opposite extremities of the octahedron were as sharply as possible focussed upon the camera screen. From one extremity of the image to the other measured closely 11 centimetres. A movement of the wires of the reading microscopes by one division of the head of the micrometer in following the expansion of the image corresponded to a diametral enlargement of this latter by 0·0005 cm., but owing to imperfect focus of the image no more than 0·001 cm. could be accurately determined. This it will be seen is the 1/11000 part of the linear dimensions of the image. If the coefficient of expansion of the substance were that of glass or that of platinum (about 0·00001), the expansion of the image due to a change of temperature of 10° C. would be fully determinable. This change of temperature would in fact produce a linear expansion of the image by the 1/10000 part of its diametral length.

It will be apparent that as the measurement we are concerned with is a ratio, that of the linear dimensions of the body when hot to its dimensions when cold, it is only necessary in the course of experiments to observe the thermal expansion of the image, if the expression is allowable. The ratio of the first and last dimension of the image being the same, of course, as the ratio of the first and last dimension of the object. The numbers quoted in this example by no means representing the final limits to which the measurements in the case of more suitably shaped bodies could be pushed, it will be seen that over wide ranges of temperature very reliable curves of expansion are attainable, supposing that the determination of temperature is equally reliable.

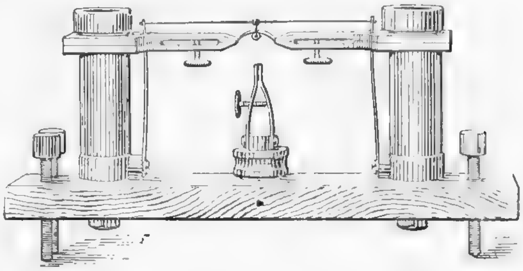

FIG. 1.

The accompanying figure (fig. 1) shows the arrangement for supporting and heating the object. The platinum oven is carried between two stout brass forceps supported upon pillars of glass. The current passes from forceps to forceps, traversing the platinum oven. The forceps carry each a shallow cup placed on the summit of the pillars in which a little mercury is poured. The wires conveying the current dip into these cups. A fine wire will be noticed spanning the space between the pillars. This wire is for the purpose of suspending the minute fragment of substance in such a manner that when heated it may not shift laterally in the field of the microscope. The wire is in fact carried at each extremity upon flat vertical springs. These rise from the base of the pillars and pass through holes slotted in the forceps. Each spring is finely notched at its upper extremity, and the crossing wire is a short length of platinum wire which has been fused at each extremity in the oxyhydrogen flame, its extremities being beaded with the fused platinum, and the length of the wire is adjusted in the flame, so that it is stretched by the springs when fitted across the notches in the latter. Any thermal change of length of the wire, due to the high temperature of the oven immediately beneath it, will be attended by the equal yielding of both springs laterally, and the central point of the cross wire will not shift.

At the central point of the cross wire the substance hangs. The ribbon forming the oven is also adjusted till the slit-like opening into the tube is beneath this central point. The tube of the oven is closely 2·3 millimetres in diameter. The manner of folding the ribbon is explained by the figure. A small globule of once melted and again solidified orthoclase is seen hanging within the oven.

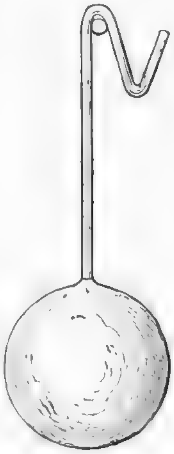

FIG. 2.

The mode of suspending this globule requires an enlarged figure for explanation (fig. 2). The bead is attached by fusion to a fine platinum wire. This wire is turned over in a sharp bend so that the cross wire described above is somewhat pinched in the bend. This friction on the cross wire is necessary, or there is risk that a vibratory motion of the bead on the least provocation would render observation impossible. An idea of the actual dimensions of the several parts of the apparatus is obtained from figure 1, this representing the apparatus to actual size.

In order to secure that any particular oven when worn out can be replaced by another oven of the same dimensions, the following mode of making the ovens was finally adopted. It will be seen later that this equality of dimensions must be secured if the thermal calibration of one oven is to be applicable to another oven replacing it.

Figure 3 shows, much enlarged, a small length of brass tube attached to the face of a vertical plate, and having a fine saw-cut made longitudinally on one side. A short length of smooth brass wire having the diameter of the interior of the oven is shown within the tube, also supported by attachment to the plate. A fold of the platinum ribbon used to form the ovens is passed round it, the ends of the ribbon being pulled through the slit in the tube, and bent downwards round the outside of the tube, being passed under the wings, and finally is cut off at the extremity of the latter. Carefully removing the ribbon from the tube, the completed oven is obtained. A number are made at the one time and preserved for use. Their position when in the forceps is shown in figure 1. The ribbon is 8 mm. wide.

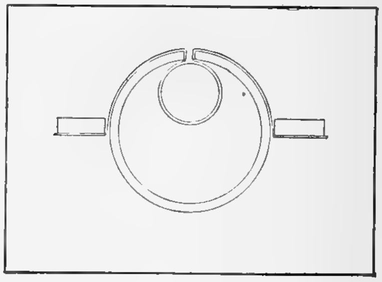
FIG. 3.

The mode of illumination in a great measure determines the degree of accuracy finally attainable. Many illuminants and optical trains were tried before that finally adopted was determined on.

The source of radiation is a small pencil of hard lime. This pencil is about 2 millimetres in diameter, and is raised at one extremity to whiteness in the oxyhydrogen flame. The lense used to condense this light upon the substance receives rays only from this minute radiant. The pencil rests upon a lime cylinder placed in its usual position in the ordinary limelight apparatus, the usual non-mixing jet adjusted to a fine point being brought to play on the extremity of the pencil.

The optical arrangements embrace, first, a good condenser of the ordinary magic-lantern type. This is carried in a tube which is freely adjustable as regards its distance from the radiant. The rays then enter the oven and fall upon the substance. This is magnified by a one-inch object-glass. The best for the purpose was found to be that of Messrs. Newton, as made for their projecting microscope. The eyepiece of the microscope is removed, the required enlargement of the image being obtained by lengthening the camera. Stray light is carefully screened from the interior of the camera.

The ordinary camera screen of ground glass must be replaced by one of far finer grain. That finally adopted was prepared as follows:—A sheet of clear glass was heated and flooded with melted paraffin wax. At the two areas where observation is to be directed large cover glasses of the thinness of that used for covering microscopic objects, and some 4 or 5 centimetres in diameter, are pressed down over the melted paraffin, expelling most of it from beneath the glasses. When cold there are thus two areas upon the screen where the texture of the paraffin is specially fine. The fineness is increased by cooling the paraffin rapidly. This is done by touching the clean side of the plate down upon the surface of cold water, while the paraffin is still melted. When cold a circle is struck with a compass upon the paraffin. The circle is so placed that it traverses the cover-glasses centrally, but, of course, is not impressed upon them, but only on the paraffin around them. This circle is 11 centimetres in diameter, and marks the dimensions and position to which the image of spherical beads of the substance is to be brought. The object of this fixed circle on the camera screen is an important one. When observation is in progress a source of error arises if the image shifts appreciably in the field of the micrometer microscopes. The fixed circle enables such a shifting to be detected at a glance. The accompanying figure (fig. 4) further explains the nature of the special screen just described.

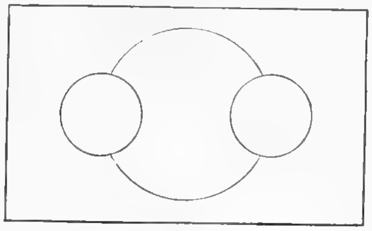

FIG. 4.

In carrying out the experiments the utmost steadiness attainable must be secured in the fixing of the train of apparatus. A stone pier with slate top was, in the case of the experiments herein described, used to carry the entire train. To the edge of the slate top the reading microscopes were clamped. Care must be taken to adjust these at such equal distances from the screen that the readings of both divided circles possess equal values, or if different the difference must be ascertained and allowed for.

The heating of the oven, and the mode of determining the temperature within it were effected as follows:—The current was supplied from a storage battery, and was controlled by a resistance handily adjustable while making observations. Lord Kelvin's graded galvanometer was used to observe the current. A current of 15 ampères, and even more than this, was occasionally employed. In practice it is not, however, necessary to determine the amount of current traversing the oven. It was found most convenient to set the sliding table at IV. on the scale of grades, and simply record the deflections of the needle when making the observations for the determination of temperature in the manner to be described.

The first mode employed to determine the temperature within the oven was to hang within it, supported from the cross wire in the ordinary manner, a spherical bead of platinum prepared in the oxyhydrogen flame by fusing the extremity of a fine wire till a bead of sufficient size had been formed. Care was taken to give this bead the dimensions that it was intended to confer upon the fused mineral beads to be in the future dealt with. This platinum bead being suspended freely in the centre of the oven, and the image sharply focussed on the screen, observations of its diametral dimensions were made under increasing strengths of current. Here the temperature is calculable from the amount of linear expansion observed. The readings of the galvanometer plotted against these temperatures afford a curve to be availed of in the after-use of the oven. Very consistent results were obtained by this method. Small variation in the dimensions of the sphere of platinum or in the thickness of the wire suspending the sphere appeared to make no appreciable difference in the curve. From one oven to another the results were nearly the same, although at this time the ovens were only roughly moulded on a wire, and the special precautions subsequently taken to secure that they were alike in all dimensions were not then taken. This method of temperature calibration was subsequently abandoned owing to a reason to be presently given; the results of the observations are, however, worthy of record.

The dimensions in what follows are given in inches. The diameter of the platinum bead or thermometer was in one set of experiments 0·06687. This was ascertained as follows:—A glass slip divided to hundredths of an inch was placed in the field of the object-glass. It was found that eight divisions on the glass were magnified to 5·22 inches on the screen, showing that the magnification was 65·2 diameters. The projection of the globule of platinum measured 4·36 inches. Its real dimension is ascertained from these data. Referring measurements to the bead and not to its image, it is further found that the reading microscopes require the cross wire to be moved through 276 divisions of the micrometer head for 0·001 inch on the divided slip. If now N is the number of divisions of the head corresponding to the increase of diameter of the bead at any observation, and if L_1 and L_2 are the first and last diameters of the bead, then $L_2 - L_1 = \frac{N \times 0{\cdot}001}{276}$, and this number divided by L_1 and by the coefficient of expansion of platinum over this range of temperature will afford the temperature of the oven. The temperatures corresponding to the expansions were directly obtained from the observations with the meldometer which I have recorded in the *Proceedings* of the Royal Irish Academy.* These observations afford the extension of a platinum ribbon when bodies of well ascertained melting points are melting in fine adherent particles upon its surface. In this manner the following points upon the required curve of galvanometer readings and temperatures within the oven were ascertained.

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* Proc. R. I. A., 3rd ser., vol. II., p. 38.

GALVANOMETER SLIDE AT IV. THROUGHOUT.

Galv.	Micrometer.	$\frac{L_2 - L_1}{L_1}$	Temperature, Centigrade.
10·4	65	0·00352	410°
12·7	83	0·00449	513
17·5	166	0·00899	926
20·0	200	0·01083	1070
21·8	220	0·01192	1155
23·9	244	0·01322	1250

A new oven was inserted in the forceps and the platinum thermometer used in the previous experiments again employed. This time the observations were as follows :—

Galv.	Micrometer.	$\frac{L_2 - L_1}{L_1}$	Temperature, Centigrade.
11·8	85	0·00461	525°
15·9	143	0·00775	820
17·9	162	0·00878	905
19·9	191	0·01035	1035
22·4	216	0·01170	1140
23·1	231	0·01251	1200

The bead used in the foregoing experiments was fused on a wire having a diameter of 0·005 inch. It was thought of interest to make a series of observations with a bead of somewhat different dimensions and on a finer wire. The new bead had a diameter of 0·063 inch, and the wire upon which it was fused was 0·003 inch in diameter.

Galv.	Micrometer.	$\frac{L_2 - L_1}{L_1}$	Temperature, Centigrade.
12·7	89	0·0051	575°
18·0	168	0·0096	975
20·6	195	0·0112	1100
22·6	220	0·0126	1205

These experiments are plotted in figure 5 (see p. 290), where the round, square, and triangular marks refer to the first, second, and third series of experiments, respectively.

The agreement between these results is satisfactory as showing the accuracy with which the readings are effected and their continuity from one oven to another, although these be even only approximately alike in dimensions. It appears, however, that the employment of a good conductor of heat as a thermometer is objectionable when the substances to be subsequently dealt with are non-conductors. This fact was ascertained in the following manner:—A bead of potassium carbonate (K_2CO_3) was prepared, having closely the dimensions of the platinum beads. The melting point of this substance, as determined by Carnelley, is 834° C. The test was made as to whether the melting point, as determined from the curve, would afford this number. It was first ascertained that the appearance of melting was perfectly characteristic and readily recognisable. From liquid to solid the change is, perhaps, most conspicuous. The phenomena will be described later. The following observations were made:—

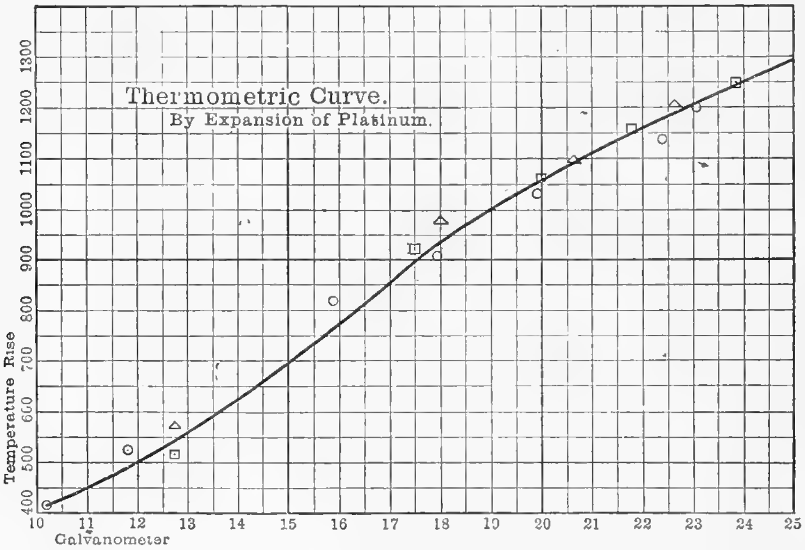

FIG. 5.

Galv.	
16·0	Not melting.
17·0	,,
17·6	Melted.
17·3	Not melted.
17·5	Slowly melting and freezing.

The temperature corresponding to 17·5 ascertained from the curves (fig. 5) is closely 900° C. These curves give the rise of temperature above that of the air. But the melting-point instead of being some 915° C. should be 834° C. There is thus an error of excess in the readings obtained from the platinum thermometer of 7 or 8 per cent. at this temperature. What is this due to? The most likely explanation is that the rise in temperature in the case of the platinum is partly effected by conductivity through the suspending wire, which very nearly touches the jaws of the slit in the top of the oven, and partly by conductivity from the heated air. On the other hand, it loses little, comparatively, by radiation. It is not impossible also that a selective absorption of rays from heated platinum by platinum may be involved. This would be of interest if it turned out to be involved, but no experiments were made to investigate the matter. In any event the temperatures, as determined by the melting of substances such as potassium carbonate, must afford closely reliable data, such bodies sufficiently resembling the substances subsequently under experiment in their physical properties, and all conditions attending the calibration and the subsequent experiments being alike. Such bodies will alike absorb and radiate freely and gain little by conductivity. It may indeed be inferred that when an error no greater than 7·5 per cent. attends the substitution of substances so different in physical properties as are platinum and potassium carbonate, but very little difference will attend the behaviour of nonconductors among themselves. The temperature assumed by the body hanging in the oven, supposing the ovens closely alike in dimensions, must be a question of the conductivity for heat and the absorptivity of the substance for the radiations to which it is exposed. The behaviour of a metal in both respects will, it may be safely assumed, differ more markedly from the behaviour of such a substance as potassium carbonate than will this last substance differ from the silicates subsequently dealt with. Except, however, investigation showed that there was some special absorption, as suggested, of the rays from heated platinum by the platinum bead, the thermometric curve determined by the platinum thermometer will be that proper to use when metallic substances are under investigation. It will be presently seen that the form of the thermometric curve, whether for metals or non-metals, is in its general features the same. The lower part of the curve is concave to the axis of temperature, the upper part convex. A general explanation of this is to be found in the fact that the rate of loss of radiation of the heated ribbon forming the oven increases rapidly with the temperature, and therefore with the current traversing it. Thus the heating effect of the current is proportional at all points to the square of the current (neglecting change of resistance of the platinum), whereas the rate of loss of heat by radiation, at first simply proportional to the temperature, will rapidly mount up. For a certain range it will also be proportional to the square of the temperature. Over this interval the thermometric curve will be approximately a right line. Ultimately the radiation loss will become more nearly proportional to the cube of the current. At this stage the curve will become convex to the axis of temperature. The course of the curve will be complicated by the electrical behaviour of platinum at the various temperatures.

A thermometric curve was now constructed by heating to their melting points beads of chloride of silver, sulphate of silver, potassium carbonate, sodium fluoride, and copper oxide. As this curve applies to some of the results recorded in this

Paper, the following particulars are given, details of the determinations being omitted. For the sake of distinguishing this curve from a subsequent curve it is called the A curve.

CURVE A.—GALVANOMETER SLIDE AT IV.

	Galv.	Melting Pt. Centigrade.
Chloride of silver, . .	11·7	451°
Sulphate of silver, . .	14·4	654
Potassium carbonate, .	17·5	834
Sodium fluoride, . .	19·0	902
Copper oxide, . . .	21·8	1055

In effecting these observations no difficulty was experienced in noting the moment of fusion. In some cases the solid bead always possessed an angular form, due to its crystallization. This suddenly disappeared at the moment of melting, to be resumed with a "hitch" at the moment of freezing. In the case of copper oxide the remarkable phenomenon is presented of a densely opaque solid becoming a deep red translucent liquid upon its melting point being attained, a behaviour suggestive in connexion with the fact of the fine transparent red of this salt when used as a colouring matter in glass. With the foregoing data as determining a thermometric curve, experiments were begun upon rock magmas.

The problem first claiming attention is that of the thermal expansion of the slag or magma of certain important types of rock. The acid, the intermediate and the basic types will be sufficiently representative generally of the innumerable grades of chemical differences obtaining among plutonic rocks. But a difficulty at once presents itself. Without a preliminary fusion and intermixture of the constituents of a large mass of any porphyritic rock, a minute bead representative of its chemical composition cannot be prepared. It would be difficult thus to prepare a reliably representative bead of the rock. The difficulty may be surmounted by the use of the glassy representatives of the types of rocks enumerated. For the acid type an obsidian may be used. For the intermediate an andesitic lava; for the basic a tachylite or basaltic glass. In this Paper the several types are not thus systematically dealt with. It appeared probable that such a mineral as orthoclase, having percentages of silica and alumina, conforming to the acid type of rock, although not to the more acid types of rock, would in its behaviour indicate the properties of the acid magma. Less volatile matter would probably be present than in a pitchstone. The pitchstone of Arran contains some 5 per cent. of volatile matter. An obsidian experimented with also showed, by its boiling, the presence of a large amount of volatile matter. Prolonged heating will indeed expel this volatile matter, but such prolonged heating is to be as far as possible avoided as probably attended with the break-up and loss of some of the fundamental constituents of the magma. The intermediate magmas are not dealt with in this Paper. The nearest representative in composition dealt with is the fusion product of the mineral augite. This has probably only some 50 per cent. of silica, thus falling short of the silica percentage of a basic-intermediate magma by some 5 per cent. of silica. Its alumina percentage is deficient and its magnesia and lime percentage excessive. Finally, the basic magma was directly dealt with in the form of a fused fragment of the basalt of county Antrim. This basalt is so fine-grained that its crystalline nature is only apparent to the eye upon very careful examination, and a small fragment may be taken as fairly representative of the rock.

From what has already been stated the mode of dealing with these bodies will be readily inferred. A bead is prepared by fusion of a small fragment of the substance. This is caused to adhere to the extremity of a very fine platinum wire. The wire being cut off and bent into a hook, in the manner depicted in figure 2, the bead is suspended from the cross wire of the heating apparatus, and adjusted till it is centrally placed within the oven. A sharp image of the spherical bead is now formed on the camera screen, the wires in the reading microscopes brought accurately into tangential contact with the image, and the reading of the micrometer heads noted down. The gradual rise in temperature of the bead is now brought about by a sliding resistance, which controls the current in the oven. At desired stages in the heating the galvanometer is read, and the wires of the micrometer readjusted upon the edge of the image, the readings of both divided heads being noted. Finally a temperature is attained when the bead no longer retains its spherical shape. Observations, then, of course come to an end. Stopping short of this a few readings may be taken from the galvanometer and micrometers while reducing the temperature of the bead. Before entering further into details as to the nature of these observations it is necessary to describe the mode of preparing the fused bead.

Two different methods may be resorted to in fusing the minute fragment of the substance. The oxyhydrogen flame may be applied directly. This will bring the more difficult fusible bodies rapidly into a liquid state. A certain amount of sodium will be visibly driven off. Boiling will ensue and last for a few seconds or for several minutes according to the nature and the degree of viscosity which the substance still retains. Finally a smooth bead will remain. The manipulation involved in this operation is very simple. The rough fragment of the substance is placed on a slip of platinum and the flame brought down to it, while at the same time it is approached with a fine platinum wire. Directing the point of the flame at the point of contact of the wire with the surface of the mineral the mineral is fused to the extreme end of the wire. Holding the wire vertically, the mineral fragment hanging downwards, the flame is then directed upon the mineral till it is brought to the desired state of fusion. The bead, finally ready for experiment, appears perfectly smooth and spherical in form, is not "strung' upon the wire, but is attached to it at its extreme point.

An alternative method is to fuse the substance entirely by radiation. This may be effected most conveniently as follows. After the attachment of the fragment to the wire, this is hung down into a narrow platinum tube, closed at the lower end. The diameter of the tube is about three millimetres, and its length a couple of centimetres. The oxyhydrogen flame is now directed to the outside of the tube till it is perceived on looking down into the tube that the globule has been formed. This method avoids the risk of chemical alteration due to the flame. It will not serve to free from bubbles the more infusible silicates, however. It serves in the case of basalt and other basic material. It is also to be observed that the colouration of the flame for the few minutes during which the bead is being prepared by the first method represents probably but a very minute loss of matter. The adjoining figure (fig. 6) represents the operation of fusing the bead by radiation.

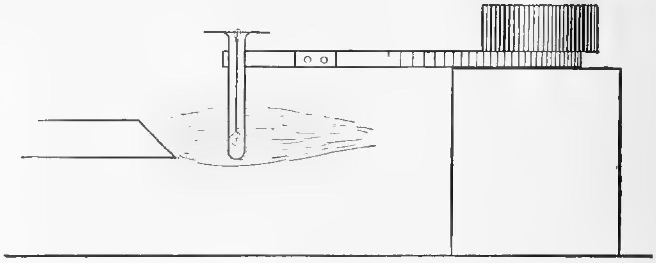
FIG. 6.

Before considering the experiments effected by this method of determining the thermal expansion of minute quantities of substances it is necessary to consider the nature and importance of the errors to which it is exposed.

The most serious source of error in effecting the measurements will arise if the substance is exposed to any marked inequality of temperature. I refer now to the case of dealing with beads at such a temperature that they owe their spherical form mainly to their surface tension and not to their rigidity. If the areas on the sphere facing the open ends of the tube still retained a certain amount of rigidity of surface while the circular band approximating to the heated platinum was completely liquefied, expansion would doubtless be attended with a certain amount of distortion of form, and the increase of diameter observed on the image would probably be unduly great. A *small* cooler area at the exposed faces of the sphere will not give rise to appreciable error in this manner as this small area will "float" out on the expanding bead without serious distortion of the spherical form. The error arising in this way will in fact depend upon the degree in which uniformity of temperature is departed from. The following observation appears to show that this departure from uniformity must be very small. A bead of potassium carbonate is formed and hung in the oven. When the melting point is reached, the adjustment of the current is refined till the bead appears to be in a fluctuating state. Now it is solid, now liquid. If these changes be very closely observed, it will be seen that they appear to originate at the centre of the exposed areas. But no adjustment was found sufficiently delicate to secure that the crystallization was for more than a moment confined to this central area. As the adjustment is capable of setting the current to the first place of decimals in the galvanometer readings (as plotted later in this Paper), and a decimal place at the slope of the curve at the point where potassium carbonate is located corresponds to a change in temperature of 10°, the inference is that the difference in temperature of the central areas from the side cannot be as much as this. For supposing that the difference was greater than this, supposing it was 20°, for example, then on adjusting the temperature of the oven so that the centre was just about to freeze, the sides will be 20° above the freezing point. Adjusting the temperature 10° lower, the centre will now be frozen, but the sides will still be 10° above the freezing point. As a matter of observation this cannot be brought about. Lowering the temperature 10° when the centre is about to freeze insures the freezing of the whole globule. On these grounds it is thought that the error arising from this source cannot be considerable or at least comparable with the order of accuracy sought to be attained.

A source of error which more obviously suggests itself is that attending changes of surface tension. The surface tension may be assumed to diminish as the fluidity gets greater, that is as the temperature rises; the amount of the change appearing to vary greatly in different substances. There are many substances which do not possess sufficient surface tension to permit of their treatment by this method. The mineral apatite almost immediately on melting runs up the wire, wetting it like oil. At high temperatures olivine behaves in a similar manner. Basalt at the highest temperatures may also climb the wire. Silver sulphate reveals remarkable effects apparently due to marked enfeeblement of surface tension, at high temperatures. Beads of this substance flatten out somewhat, turning the flat faces towards the hot platinum. The bead in fact owes this distortion to a different distribution of surface tension over its surface. This substance when melted on platinum, runs over it like a thin oil. But observations on a great variety of salts and minerals show images which retain their spherical form till temperatures above the melting point. Thus orthoclase, according to observations on the meldometer, melts at 1175° C. It was found practicable to carry measurements of its expansion up to about 1400° C. This substance remains viscous probably even at this temperature; it indeed softens at so low a temperature as 865° C. No change of sphericity can be perceived. The basalt experimented with melted on the meldometer at 1153°, and runs about rapidly at 1173°. Perfect retention of form was shown till nearly

1200°. The bead breaks up then by the formation of bubbles which apparently rise by gravity within it, blowing out generally at its higher surface. Figure 7 is copied as accurately as possible from two photographs of the image of an augite bead at 15° C. and at 1120° C., the photographs being successively printed on the one surface. Transparent liquid beads of salts, such as potassium carbonate, can be observed, presenting the singular appearance of a transparent red hot liquid; revealing, in fact, the extremity of the suspending wire within.

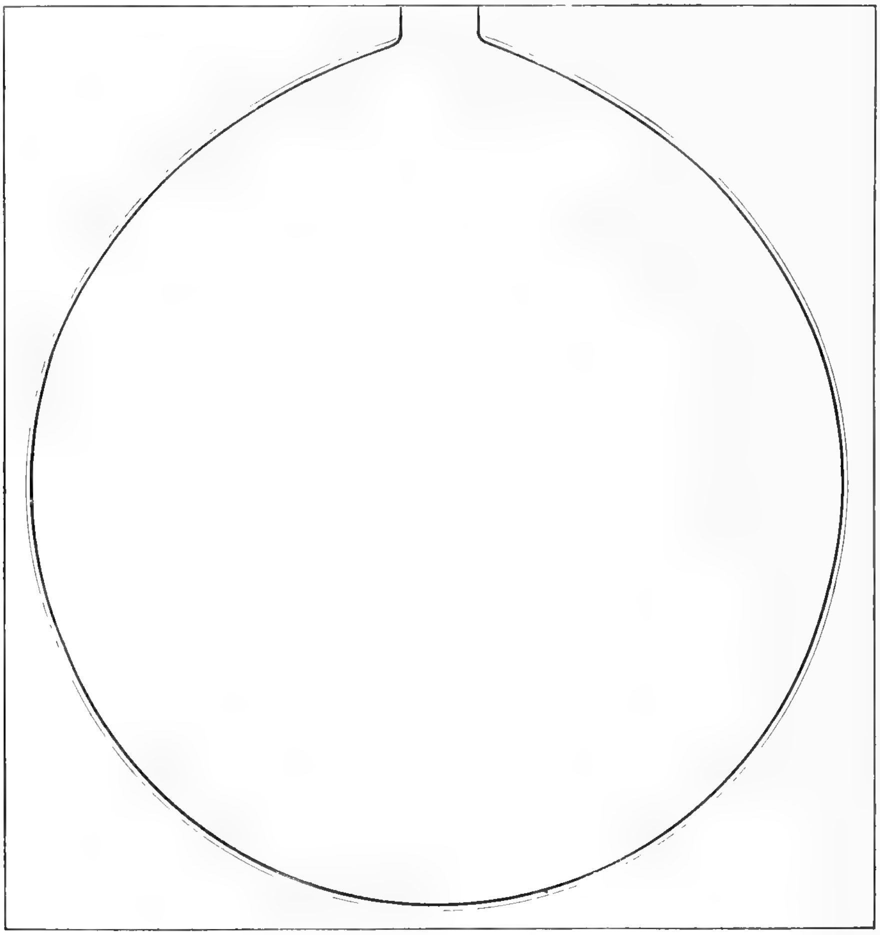

FIG. 7.

The fact must not be forgotten in further considering the liability to error from this source, that a change of surface tension will cause no error so far as gravitational effects are concerned, provided this change does not mean reduction of surface tension below a certain amount, that requisite to secure the retention of the spherical form against the weight of the bead. In many familiar cases, substances at high temperatures and perfectly liquid show that they possess considerable surface energy. The rounding of shot grains is effected against very considerable gravitational force owing to the very high density of lead. Tait,* in speaking of capillarity, points out that "the almost perfect sphericity of the little bead formed on the end of a glass fibre which is held in a flame for a short time" enabled many of the triumphs of the modern microscope to be anticipated.

The small size of the beads used in these experiments is of course a source of protection against gravitational distortion. The force acting per unit of length radially inwards on any great circle is inversely as the radius of the sphere. Small spheres must in some cases experience considerable *compressive* stress. Relief of this stress at higher temperatures will not therefore necessarily be attended with distortion due to gravitational effects.

Any considerable downward shifting of the image will be attended with error. But it will be apparent from figure 7 that this shift must be so considerable as to be at once visible before appreciable error will be introduced. The circle struck on the camera screen will enable a shift of less than a millimetre to be perceived. But such a shift need not demand rejection of the experiment or even allowance for it to be made.

Against the possibility of some error from the sources quoted are to be set the peculiar advantages which this mode of experimenting presents when dealing with such substances as the silicates. In large masses it is quite impossible to free the more acid magmas from bubbles. But it was found in most cases not difficult to accomplish this in the case of the extremely small quantities going to make a bead. Again, measurements which involve the use of a containing vessel introduce the difficulty of allowing for the expansion of this vessel at high temperatures. This difficulty is even less considerable than that of observing accurately the change of volume of the magma within the vessel. The observations in the present method are effected under the same conditions of ease as we measure the size of a body under the microscope. Of course in certain cases the ability to deal with so small a quantity of the substance will enable observations to be carried out which otherwise were impracticable.

BASALT.

The following are the observations which determine the curve of expansion of the basalt of the Giant's Causeway, Co. Antrim, as given in Plate XVIII.

The bead was melted in the oven directly, being introduced as a rough fragment attached to the suspending wire. Diameter on screen 3·54 inches. As 4·60 inches on the screen represent 0·07 inch closely, at the position of the bead, the actual diameter of the bead is 0·054 inch. Also 268 divisions of the micrometer

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* "Properties of Matter," p. 231.

head are required to traverse 0·001 inch placed in the position of the bead. Hence:—

$$\frac{L_2 - L_1}{L_1} = \frac{N \times 0{\cdot}001}{268 \times 0{\cdot}054}.$$

Galv.	Temperature, Centigrade.	Micrometer. N.	$\frac{L_2 - L_1}{L_1}$	$\frac{V_2 - V_1}{V_1}$
10·3	360°	38	0·00262	0·00786
13·2	550	53	0·00366	0·01098
14·5	650	67	0·00463	0·01389
15·0	680	75	0·00518	0·01554
15·7	720	83	0·00574	0·01722
17·8	840	110	0·00760	0·02280
19·1	900	126	0·00870	0·02610
20·1	950	144	0·00995	0·02985
23·1	1090	182	0·01257	0·03771
24·0	1135 q. p.	197	0·01361	0·04083
24·9	1165 q. p.	287	0·01983	0·05949

The following measurements of the volume contraction of molten diabase, by C. Barus (American Jour. of Science, vol. 42, p. 498), are, when overlapping, in approximate agreement with the foregoing numbers.

Temperature, Centigrade.	$\frac{(V_t - V_0)}{V_0}$
1421°	0·0771
1388	0·0760
1319	0·0730
1305	0·0721
1190	0·0661
1163	0·0652
1112	0·0628
1093	0·0285
914	0·0223
855	0·0202

Barus records that this rock was sticky at 1190°, and very sticky at 1163°. Of course the composition of the two rocks will probably only possess approximate likeness. The results of Roberts-Austin and Rucker on the specific heat of basalt at high temperatures appears to show by the large absorption of heat in the neighbourhood of 800° C. that melting occurs at this temperature in the case of the sample dealt with. To settle the question of the melting point of the Giant's Causeway basalt I made determinations on the meldometer. At a temperature of

1095° the finest dust was adhering to the platinum ribbon. At 1135° this stickiness had become more marked. At 1173° the basalt particles were running rapidly on the platinum ribbon; 1153° was finally noted as a temperature at which small fragments slowly gather into rounded beads. This is of course a true liquid state, surface tension forces coming into operation.

DIAMOND.

The next determination made with this oven was the thermal expansion of diamond. As this determination marks another application of this method, and in its results serves to confirm its value, it is given here.

The image on the screen scaled 4·70 inches, 0·07 inch placed in the position of the object, scaled 4·60 inches. The diameter of the diamond, from solid angle to solid angle, was therefore 0·0715 inch. Also 0·001 inch, in the position of the object, measured 268 divisions of the micrometer beads. Hence

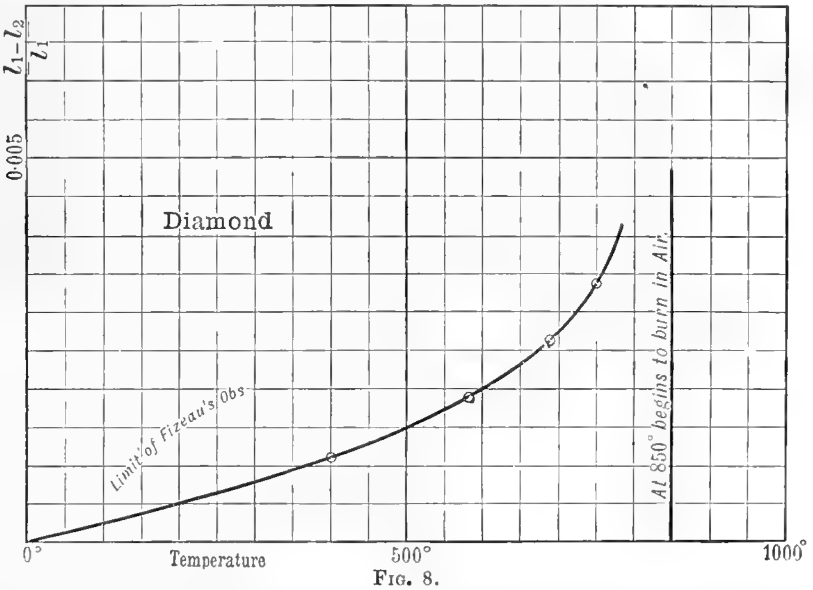


FIG. 8.

$$\frac{L_2 - L_1}{L_1} = \frac{N \times 0{\cdot}001}{268 \times 0{\cdot}0715}.$$

Galv.	Temperature, Centigrade.	Micrometer. N.	$\frac{L_2 - L_1}{L_1}$	$\frac{V_2 - V_1}{V_1}$
11·1	400°	22	0·00114	0·00342
13·6	580	37	0·00193	0·00579
15·1	686	51	0·00265	0·00795
16·2	750	65	0·00338	0·01014

These are plotted in figure 8. At a temperature of 850 the diamond began to burn rapidly. Its surface soon became stepped in a manner characteristic of certain crystals, and as Professor Judd has recently (Trans. Roy. Soc. vol. 187 A, p. 222) shown, often exhibited in the case of the Burmese rubies. Once commenced, the combustion continued till the oven was cooled down to about 712°. The peculiar appearance of this diamond after removal from the oven is shown in Plate XVII., which is from a photograph. The enlargement is 65 diameters. In these experiments on diamond the little vertical forceps seen in figure 1 was called into requisition. The oven is inverted, the slit being downwards. The diamond was held in a cradle of platinum wire clipped in the forceps, and so that it occupied the centre of the oven.

It is not in place to consider these experiments here. It may be pointed out, however, that they appear to meet tangentially those of Fizeau, but the latter experiments are confined to a remotely placed range of temperature.

AUGITE.

The following observations on augite are referable to the thermometric curve used in the preceding. The bead was prepared in the oxyhydrogen flame, and was probably free from bubbles. Diameter of bead 0·064 inch.

Galv.	Temperature, Centigrade.	Micrometer.	$\frac{L_2 - L_1}{L_1}$	$\frac{V_2 - V_1}{V_1}$
17·5	820°	107	0·00592	·01676
18·0	850	112	0·00620	·01860
18·9	890	123	0·00681	·02043
11·7	440	52	0·00288	·00864
16·0	740	96	0·00531	·01593
17·6	830	168	0·00598	·01794
19·05	900	123	0·00681	·02043
20·5	970	141	0·00781	·02343
9·75	335	33	0·00183	·00549
22·6	1068	151	0·00836	·02508
23·0	1085	174	0·00963	·02889
21·9	1040	161	0·00892	·02676
23·5	1110	190	0·01052	·03156
23·8	1120	195	0·01080	·03240

At a temperature of 1120° a photograph of this bead was taken, and again after it had been cooled to air temperature. These have been previously referred to, and are reproduced, in outline, as far as possible, accurately in figure 7.

It will be noticed in making these observations that the temperature was not steadily altered in one direction, but observations were made at various temperatures consecutively. They are nevertheless, as will be seen by the curve (Plate XVIII.), very consistent with one another. The curve is marked "Augite I."

At this stage of the experiments a standard method of shaping the ovens was introduced. The form of oven was a little altered. Some alteration was also made in the form of the forceps which supports the oven; these were in fact brought to the form shown in figure 1. These alterations necessitated a fresh thermometric curve. The following readings fix the course of this curve:—

CURVE B.

Substance.	Galv.	Melting Pt. Centigrade.	Rise of Temp. Plotted.
Sulphur, . .	7·05	114°·5	99°·5
Silver chloride, .	13·25	451	436
Silver sulphate, .	15·9	654	639
Potassium carbonate,	19·2	834	819
Copper oxide, . .	22·5	1055	1040
Palladium, . .	31·1	1500	1485

This last point, it is true, is open to the suspicion that, as in the case of the platinum beads, the temperature taken up by a metal will be greater than that taken up by a non-conductor of heat. The error introduced in this manner may be as much as 7·5 per cent.

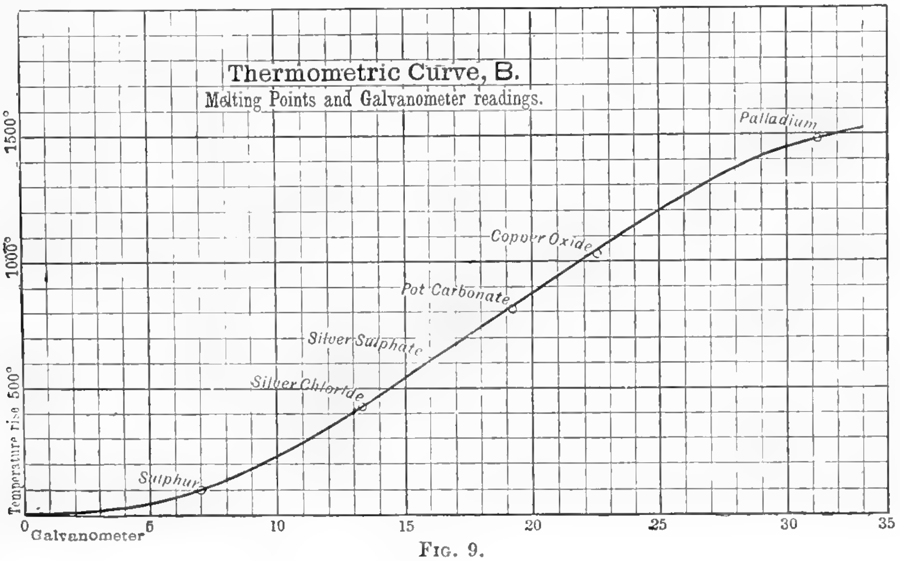


FIG. 9.

In valuing estimates effected at the highest readings on the curve, this possibility must be borne in mind. They cannot claim close accuracy. The curve is reproduced in figure 9. Its general resemblance to that determined by the expansion of platinum will be recognised.

Taking this curve into use, the following observations on augite were made. This specimen of augite was in the form of crystals having the prism angle of 87°, and black in colour. The former augite dealt with was fragmentary and more transparent.

The present specimen was prepared by radiation in the platinum tube. Its diameter was 0·06 inch.

Galv.	Micrometer.	$\frac{L_2 - L_1}{L_1}$	Temperature, Centigrade.	$\frac{V_2 - V_1}{V_1}$
10·85	31	0·0018	340°	0·0054
14·3	74	0·0043	520	0·0129
15·9	98	0·0057	615	0·0171
19·1	194	0·0110	810	0·0330

On raising the temperature to 1320°, a bubble blew out and put an end to the experiments. The noteworthy difference between this curve and that formerly found for augite is probably to be referred, principally, to the presence of minute vesicles in the present specimen. The presence of bubbles will tend to render the curve of expansion steeper, and the accident which put a stop to these experiments appears to confirm this idea.

The natural expansion so found is, however, not without its teaching, with reference to lavas fused under low pressure.

This curve is given on Plate XVIII., and is marked Augite II.

ORTHOCLASE.

The series of experiments was closed with an observation on orthoclase (Plate XVIII.). The bead was prepared in the oxyhydrogen flame. It was soon rendered quite clear and was visibly free from vesicles.

The diameter of the bead was 0·056 inch.

Galv.	Micrometer.	$\frac{L_2 - L_1}{L_1}$	Temperature, Centigrade.	$\frac{V_2 - V_1}{V_1}$
12·0	26	0·0016	390°	0·0048
16·3	50	0·0031	640	0·0093
19·9	68	0·0043	860	0·0129
23·4	94	0·0059	1090	0·0177
25·8	130	0·0081	1240	0·0243
27·1	150	0·0094	1320	0·0282
27·8	140	0·0088	1350 ?	0·0264
28·7	210	0·0132	1400 ?	0·0396

Meldometer observations show that this body softens at 865° C. The curious phenomenon was observed in the course of these experiments of the platinum subliming and growing in crystals on the surface of the highly heated bead. This indeed rendered the bead useless for further treatment, although conferring upon it a very beautiful appearance. A similar phenomenon was previously noticed attending the use of the meldometer. (*Nature*, XLIV., 1891, p. 124.)

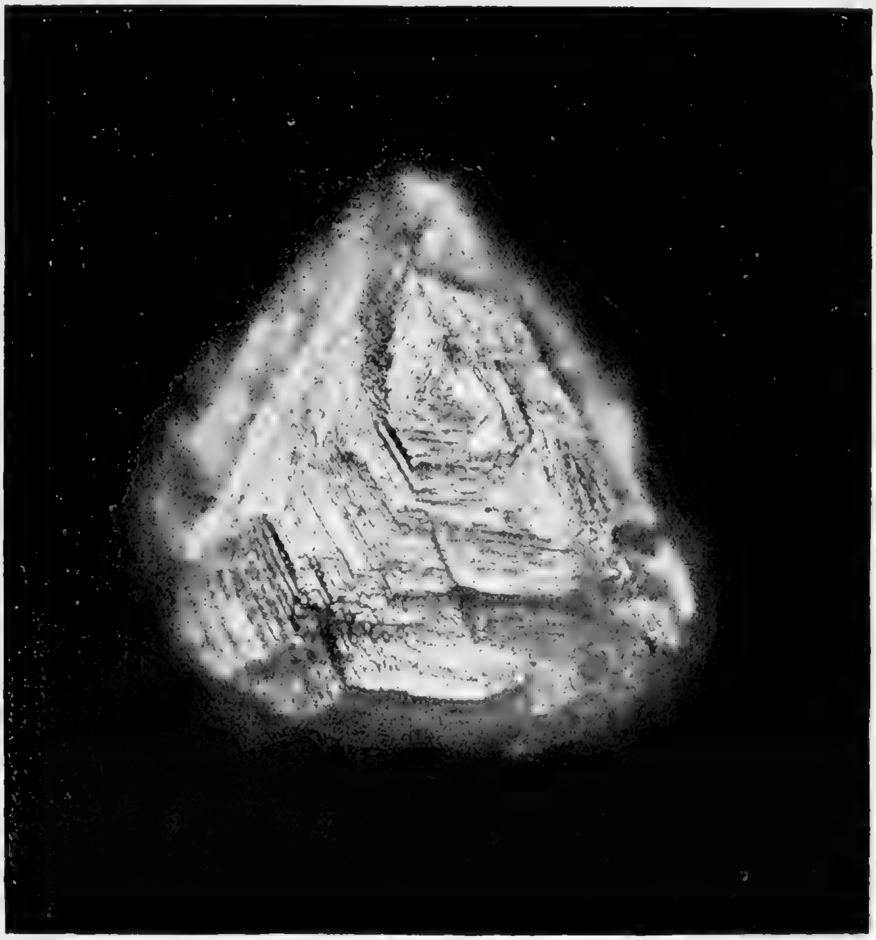
Finally, a considerable number of experiments were made to determine the conditions under which bubbles were developed in basalt. Above a certain temperature, in most cases, the basalt of the Giant's Causeway evolves minute bubbles. Careful melting at a temperature short of this gave, generally, a bead free from vesicles. The bubbles developed at high temperatures could be driven off in the oxyhydrogen flame without any apparent change in the specimen and seemingly with but little loss. It is very certain that observations made on beads deprived of bubbles in this manner will more probably indicate volume changes occurring at considerable depths below the Earth's surface than will beads in which the development of minute vesicles is permitted. Under conditions of high pressure the presence of volatile matter can hardly be supposed to seriously effect the volume-changes attending changes of temperature.

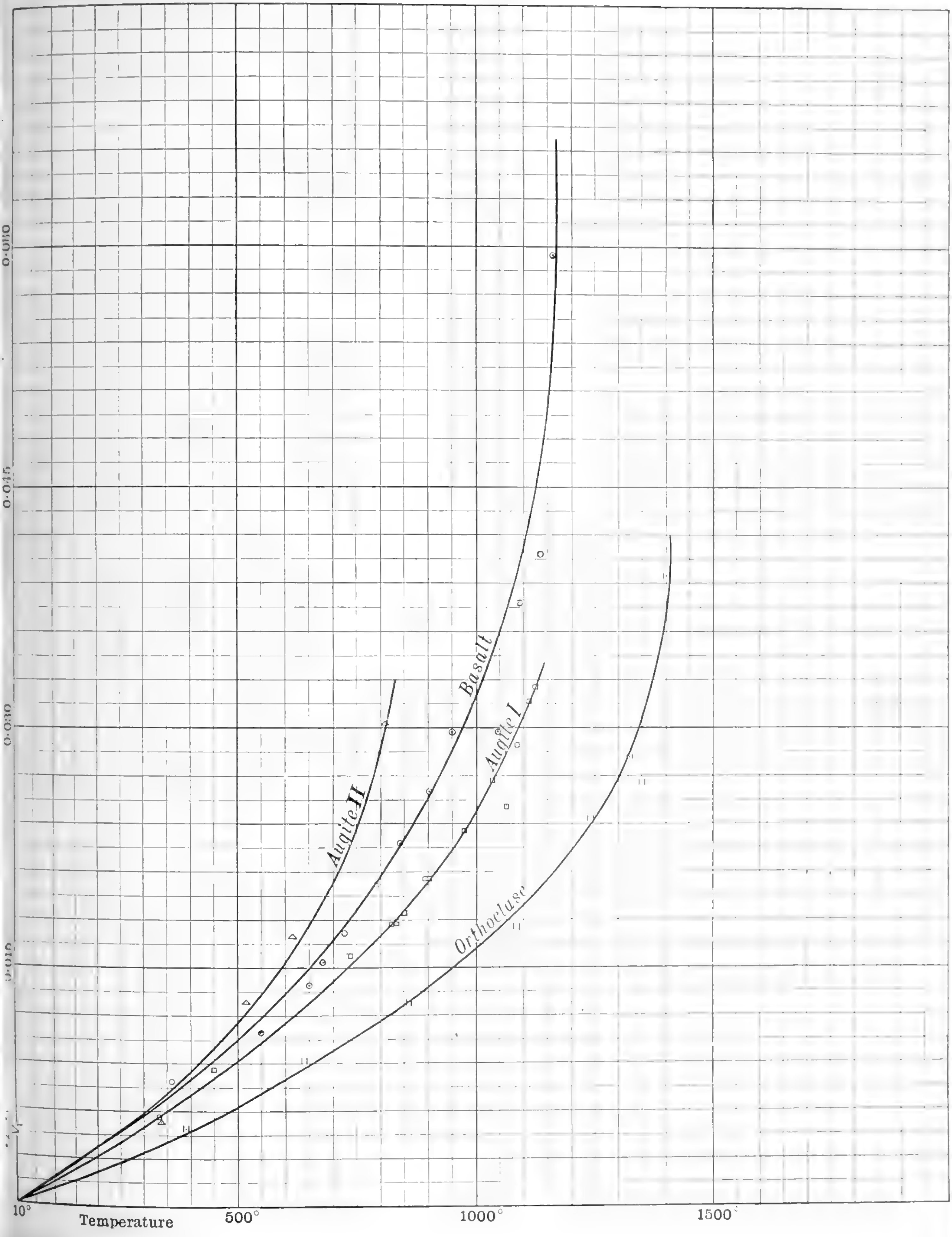
NOTE ADDED IN THE PRESS.

The Artificial Production of Diamond.—In the number of *Nature* (March 22, 1894) in which I described the results obtained by the foregoing method as applied to the thermal expansion of diamond, I referred to the probability that, in the remarkable rapid thermal expansion, at high temperatures, of this substance, a clue to the requisite experimental conditions for its artificial production would be found. In short, that it was probable that the molecular operation, whereby the crystalline form of carbon changed to the amorphous form at the temperature of about 800° C., might, under suitable experimental conditions, be caused to take place in the reverse direction. If this surmise was correct, then high pressure applied while the amorphous carbon was maintained at a high temperature (somewhere about 1000° C.) ought alone to suffice to bring about the artificial formation of diamond. These ideas, indeed, induced me at that time to undertake some experiments on these principles, but without definite success, principally owing to the yielding of the containing cylinders at the high temperatures. The success of M. Moisson by the simultaneous application of high pressure, high temperature, and the solvent action of iron on carbon, occurred about this time, and I laid aside my experiments. At the same time I still ventured to question the necessity of the coexistence of the last-mentioned of M. Moisson's conditions along with the first two.

In a recent number of *Nature* (September 23rd, 1897), it appears that the artificial production of diamond has now been accomplished under the action of the first two conditions only. This appears to confirm the idea that the process of the formation of diamond by artificial means may be regarded as a case of crystallographic reversibility. It will probably turn out before long that this matter will possess an important commercial bearing, as well as being of considerable scientific interest.

September 30th, 1897.




0·060
0·045
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v_t
10°
Temperature
500°
1000°
1500°
Augite II
Basalt
Augite I
Orthoclase

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[Received October 25, 1897.]

CONTENTS.

Introduction.

The present writer began early in the sixties to investigate the phenomena of atmospheres by the kinetic theory of gas, and in 1867 communicated to the Royal Society a memoir,* which pointed out the conditions which limit the height to which an atmosphere will extend, and in which it was inferred that the gases of which an atmosphere consists attain elevations depending on the masses of their molecules, the lighter constituents overlapping the others. This was disputed at the time, on account of its supposed conflict with Dalton's law of the equal diffusion of gases†; but physical astronomers now recognise its truth.

On the 19th of December, 1870, the author delivered a discourse before the Royal Dublin Society, which was the first of the series of communications, of which an account is given in the following pages. One of the topics of that discourse was the absence of atmosphere from the Moon. This was accounted for by the kinetic theory of gas; inasmuch as the potential of gravitation on the Moon is such that a free molecule moving in any outward direction with a velocity of

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* See an extract from this Memoir on p. 307, below.

† According to the Kinetic Theory, Dalton's Law will be true of mixtures of gases if the free paths of the molecules between their encounters are straight. This is the case, to an excessively close approximation, in all laboratory experiments; but the law ceases to hold at elevations in the atmosphere where the longer and more slowly pursued free paths are sensibly bent by gravity.

2·38 kilometres* per second would escape, and, accordingly, the Moon is unable to retain any gas, the molecules of which can occasionally reach this speed at the highest temperature that prevails on the surface of the Moon.

Shortly after, a second communication was made to the Royal Dublin Society, at one of its evening scientific meetings, based on the supposition that the Moon would have had an atmosphere consisting of the same gases as those of the Earth's atmosphere, were it not for the drifting away of the molecules. It was shown that if the molecules of these gases can escape from the Moon, it necessarily follows that the Earth is incompetent to imprison free hydrogen; and this was offered as explaining the fact that, though hydrogen is being supplied in small quantities to the Earth's atmosphere by submarine volcanoes and in other ways, it has not, even after the lapse of geological ages, accumulated in the atmosphere to any sensible extent. This communication was followed at intervals by others, in which the investigation was extended to other bodies in the Solar system, in which an endeavour was made to trace what becomes of the molecules that filter away from these several bodies, and in which it was suggested that the gap in the series of terrestrial elements between hydrogen and lithium may be accounted for by the intermediate elements [except helium] having escaped from the Earth at a remote time, when the Earth was hot.

In one of the earlier of these communications, it was pointed out that it is probable that no water can remain on Mars—a probability which is now raised to a certainty by the recent discovery, that helium (with a molecular mass twice that of hydrogen) is being constantly supplied in small quantities to the Earth's atmosphere by hot springs, and probably in other ways, and that nevertheless there is no sensible accumulation of it in the Earth's atmosphere after the infiltration has been going on for cosmical ages of time. In the absence of water, carbon dioxide was suggested as, with some probability, the substance that produces the polar snows upon Mars. Moreover, on the Earth, snow, rain, and cloud are produced by the lightest constituent of our atmosphere; but if the atmosphere of Mars consist of nitrogen and carbon dioxide, snow, frost, and fog on that planet are being produced by the heaviest constituent. An attempt was made to follow out the consequences of this state of things, and to refer to it those recurring appearances upon Mars which, though very imperfectly seen owing to the great distance from which we observe them, have been (perhaps too definitely) mapped and described under the name of canals.

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* It is very desirable that the names of metric measures should be made English words, and pronounced as such. Thus kilometre, hektometre, and dekametre should be pronounced with the accent on the second syllable as in thermometer, barometer, &c. This would have the further useful effect of better distinguishing these names from decimetre, centimetre, and millimetre, which have accents on the first and third syllables.

Of this series of communications, though known to many, only imperfect printed accounts have appeared; and it is the object of the present communication to present the subject in a more complete form. The opportunity will be taken of substituting better numerical results for those originally given, by basing them on the fact which has recently come to our knowledge, that not only hydrogen, but helium also, with a density twice that of hydrogen, can escape from the Earth. The most notable change that this makes is, that what was before probable is now certain—that water cannot in any of its forms be present upon Mars.

CHAPTER I.—*Of the Fundamental Facts.*

In order to see why neither hydrogen nor helium remains in the Earth's atmosphere, and why there is neither air nor water on the Moon, it is necessary to understand the conditions which determine the limit of an atmosphere. These were investigated under the kinetic theory of gas by the present writer in a memoir communicated to the Royal Society in May, 1867: see his Paper "On the Physical Constitution of the Sun and Stars" in the *Proceedings of the Royal Society*, No. 105, 1868, from page 13 of which it will be convenient to make the following extract*:—

"23. Let us consider what it is that puts a limit to the atmosphere. Let us first suppose that it consists of but one gas, and let us conceive a layer of this gas between two horizontal surfaces of indefinite extent, so close that the interval between them is small compared with the mean distance to which molecules dart between their collisions, but yet thick enough to have, at any moment, several molecules within it. Molecules are constantly flying in all directions across this thin stratum. Some of them come within the sphere of one another's influence while within the layer, and therefore pass out of it with altered direction and speed. Let us call these the molecules emitted by the layer. If the same density and pressure prevail above and below the layer, the molecules which strike down into it will, on account of gravity, arrive with somewhat more speed on the average than those which rise into it. Hence those molecules which suffer collision within the stratum will not scatter equally in all directions, but will have a preponderating downward motion, so that of the molecules emitted by the stratum more will pass downwards than upwards. This state of things is unstable, and will not arrive at an equilibrium until either the density or the temperature is greater on the underside of the layer. If the density be greater, more molecules will fly into the stratum from beneath than from above: and if the temperature be greater the molecules will strike up into it, both more frequently and with greater speed. In the Earth's atmosphere it is by a combination of both these that the equilibrium is maintained: both the temperature and the density decrease from the surface of the Earth upwards.

"24. We have hitherto taken into account only those molecules which, after a collision, have arrived at the stratum from the side on which the collision took place. But besides these there will be a certain number of molecules which, having passed through the stratum from beneath, fall back into it without

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* Further information on this subject will be found in sections 22, 24, 25, 26, and in the footnote to section 93, of the paper here quoted.

having met with other molecules, either by reason of the nearly horizontal direction of their motion, or because of its low speed. The number of molecules that will thus fall back into the stratum will be a very inconsiderable proportion of the whole number passing through the stratum, so long as the temperature and density are at all like what they are at the surface of the Earth. In the lower strata of the atmosphere, therefore, the law by which the temperature and density decrease will not be appreciably affected by molecules thus falling back. But in those regions where the atmosphere is both cold and very attenuated, where accordingly the distance between the molecules is great and the speed with which they move feeble, the number of cases in which ascending molecules become descending without having encountered others will begin to be sensible. From this point upwards the density of the atmosphere will decrease by a much more rapid law, which will within a short space bring the atmosphere to an end."

It appears, then, that the atmosphere round any planet or satellite will, *cœteris paribus*, range to a greater height the less gravity upon that body is; and that if the potential of gravitation be sufficiently low, and the speed with which the molecules dart about sufficiently great, individual molecules will stream away from that body, and become independent wanderers throughout space.

Thus, we shall presently see that, in the case of the Earth, a velocity of about eleven kilometres per second (nearly seven miles) would be enough to carry a molecule at the boundary of our atmosphere off into space, if the Earth were alone and at rest; and a somewhat less velocity of projection (about 10·5 km. per second) is sufficient, on account of the rotation of the Earth, and because westerly winds sometimes blow in the upper regions of the atmosphere. The modification introduced by these subsidiary causes will be examined in Chapter IV., and the amount of their effect will be determined. The behaviour of molecules is also slightly affected by the Moon, which is near enough sensibly to alter the orbits of molecules if shot up in some directions.

Let us now consider what would happen if free hydrogen could remain in our atmosphere. Hydrogen is, in modern times, being supplied in small quantities to the Earth's atmosphere by submarine* volcanoes and in other ways. Even if there were no tendency in hydrogen to leak away, it could not in the free state become a *large* constituent of our atmosphere, because, when it came to be a certain proportion of the atmosphere, it would, on the occasion of the first thunderstorm or on account of fires, enter into combination with the oxygen which is, in modern times, a large constituent of the atmosphere: but after each such explosion it would accumulate until it became a minor constituent like carbon dioxide were it not for the events described in this Paper; and in former times, before there was vegetation to evolve free oxygen, it might have been a large constituent but for those events. The free hydrogen which continues in modern times to be supplied in small quantities to the atmosphere is used up in some way. A little may be occluded, some may suffer surface condensation, and the rest is escaping.

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* The hydrogen evolved by terrestial volcanoes burns into water on reaching the air, and ceases to be free hydrogen.

The evidence that there is an escape of gas from the Earth's atmosphere is still more conspicuous in the case of helium. Small quantities of this gas are constantly being dribbled into the atmosphere by hot springs and probably in other ways, and it was probably supplied more copiously in former times. Now helium is so little disposed to enter into combination with other elements, that the efforts of chemists to effect any such union have been unavailing. We must conclude, therefore, that this gas remains unchanged within the atmosphere, where it would therefore, in the lapse of time, have accumulated so as to be now a sensible and perhaps a large constituent of the Earth's atmosphere were it not that it is escaping from the atmosphere's outer boundary as rapidly as it enters it below—indeed so promptly escaping, that the amount *in transitu* is too small for the appliances of the chemist to detect it.

On the other hand, water is not sensibly leaving the Earth. From which we learn that the potential of the Earth and the temperature at the boundary of its atmosphere are such as enable our planet effectually to imprison the vapour of water with molecules whose mass compared with molecules of hydrogen is 9 (and probably ammonia with a density of 8·5). The other constituents of the Earth's atmosphere, such as nitrogen, oxygen, and carbon dioxide, have still heavier molecules. Accordingly, none of these escape in sufficient numbers to produce any perceptible diminution of the quantity of gas upon the Earth.* We may infer from this that *the boundary between those gases that can effectually escape from the Earth and those which cannot, lies somewhere between gas consisting of molecules with twice the mass of molecules of hydrogen and gas with molecules whose mass is nine times*† *the mass of molecules of hydrogen.*

This we may take to be one fact which we can ascertain by observing what occurs upon the Earth, and the telescope has been able to reveal to us another fact of a like kind, viz. that there is either no atmosphere upon the Moon, or excessively little—a fact which has been made certain by the application of very delicate tests.

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* We need not suppose that there is absolutely no escape of the molecules of the denser gases, but only that the event is an excessively rare one. Thus, if the molecules of a gas escape so very seldom that only a million succeed in leaving the entire atmosphere of the Earth in each second, then a simple computation will show that it would take rather more than thirty millions of years for a uno-twentyone (the number represented by 1 with 21 cyphers after it) of these molecules to have escaped. Now a uno-twentyone is about the number of molecules which are present within every cubic centimetre of the gas at such temperatures and pressures as prevail at the bottom of our atmosphere. An escape of molecules of the denser constituents of the atmosphere on this excessively small scale, or even on a scale considerably larger, may be and probably is going on. See a paper on the "Internal Motions of Gases" in the *Philosophical Magazine* for August, 1868, where the number of molecules in a gas is estimated. Readers of that paper are requested to correct a mistake at the end of the third paragraph, where 16^2 was by an oversight inserted instead of $\sqrt{16}$.

† We shall find in the Chapter on Venus that the presence of water on that planet enables us to somewhat lower the upper of these two limits.

CHAPTER II.—*Interpretation by the Kinetic Theory.*

In order to make these facts the starting-point for fresh advances, we must study their precise physical meaning when interpreted by the kinetic theory of gas.

The velocity whose square is the mean of the squares of the velocities of the individual molecules of a gas—"the velocity of mean square" as it has been called—was determined* by Clausius to be

$$w = 485\sqrt{\frac{T}{273}\frac{}{\sigma}} \text{ metres per second,}$$

where w is the velocity of mean square, T the absolute temperature of the gas measured in Centigrade degrees, and σ its specific gravity compared with air. We shall find it convenient to use ρ instead of σ, where ρ is the density of the gas compared with hydrogen. Accordingly $\sigma = \rho / 14{\cdot}4$, whereby Clausius's formula becomes

$$w = (111{\cdot}4)\sqrt{\frac{T}{\rho}}, \qquad (1)$$

in metres per second. This formula gives a velocity of 1603 metres, nearly a mile a second as the "velocity of mean square" in hydrogen at an absolute temperature of 207°, *i.e.* at a temperature which is 66° C. below freezing point. This is the "velocity of mean square" of the molecules of hydrogen in an atmosphere consisting either wholly or partly of hydrogen, at any situation in which the gas is at that low temperature. Similarly by putting $\rho = 2$ and $T = 207$, we find the velocity of mean square for helium at the same low temperature. It is about 1133 metres per second. The actual velocities of the molecules are, of course, some of them considerably more and others considerably less than this mean, even if the hydrogen or helium be unmixed with other gases; and the divergences of some of the individual velocities from the mean will become exaggerated when the encounters to which the molecules of these lighter gases are subjected are sometimes with molecules many times more massive, and which may, when the encounter takes place, be moving with more than their average speed, as must often happen in our atmosphere. Under these circumstances we should be prepared to find that a velocity several times the foregoing mean is not unfrequently reached; and the evidence (see Chapter IV.) goes to show that *a velocity which is between nine and ten times the velocity of mean square*, a velocity which is able to carry molecules of either hydrogen or helium away from the Earth, *is sufficiently often attained to make the escape of gas effectual.*

We are now in a position to aim at making our results so definite that they may be extended to other bodies in the Solar system.

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* *Philosophical Magazine*, vol. XIV. (1857), p. 124.

CHAPTER III.—*Dynamical Equations.*

In making our calculations with reference to the planets and satellites of the Solar system, it will simplify the work, and be sufficient for our purpose, to treat them as spherical bodies, consisting of layers each of which is a spherical shell of uniform density. In that case, if B be one of these bodies

$$a \text{ (the acceleration at the surface of } B\text{, due to attraction)} = \frac{M}{R^2}, \qquad (2)$$

and

$$K \text{ (the potential of gravitation at its surface)} \quad . \quad . \quad = \frac{M}{R}, \qquad (3)$$

where M is the mass of B, and R the radius of its spherical surface.

Now K, the potential, as we learn in the science of Dynamics, expresses the kinetic energy stored up per unit of mass by a small* body in falling upon the surface of B from infinity. Hence,

$$K = \frac{v^2}{2}, \qquad (4)$$

where v is the velocity which would be acquired by a small mass in falling from infinity. If a missile were projected from B with this speed, it would just be able to reach infinity, *i.e.* this speed is the least which would enable a molecule to get completely away from B. We may, therefore, call it *the minimum speed of*

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* By a small body is to be understood one whose mass bears to the mass of B, a ratio so small that, from the physical standpoint, it may legitimately be regarded as a small quantity of at least the first order. For this purpose, a ratio of a tenthet, that is, of a unit in the tenth place of decimals, is sufficiently small in almost every branch of physical inquiry. If M be the mass of B, and m the mass of the body falling upon it, then the energy changed from potential into kinetic energy, by allowing them to fall together from infinity,

$$= \frac{mv^2}{2} + \frac{MV^2}{2},$$

if we suppose them to have started from rest, and if on coming together they have acquired the velocities V and $-v$. Now, by the Principle of the Centre of Mass, $MV + mv = 0$. Therefore the acquired kinetic energy may be written

$$= \frac{mv^2}{2}\left(1 + \frac{m}{M}\right),$$

which differs from being

$$= \frac{mv^2}{2}$$

by an insensible quantity if the ratio m/M is sufficiently small. And it is much more than sufficiently small from the physical standpoint, in the cases we are concerned with, where m is the mass of a gaseous molecule, and M the mass of a planet or satellite. In fact m is here of about the fifth order of small quantities compared with M, if we take a tenthet (10^{-10}) as about the ratio between quantities of two consecutive orders.

escape from B when B is at rest. If B rotates, a less velocity relatively to the surface of B will suffice, provided that the missile is shot off in the direction towards which the station from which it starts was being carried by the rotation at the instant of projection.

CHAPTER IV.—*Of the Earth.*

Let us apply these elementary dynamical considerations to the Earth. In doing this, we may assume—

R (the Earth's equatorial radius), . . = 6378 kilometres.
h (the height of the atmosphere), . . = 200 km.
g (gravity at E, a station on the equator, at the bottom of the atmosphere), . . = 978·1 cm. / sec. / sec.
u (the velocity at the equator due to the Earth's rotation), ... = 464 m. / sec.

We shall need one other datum, viz. the highest temperature which can be reached by the air at station E', where E' is a station at the top of the atmosphere, over the equator. To enable us to arrive at definite results, we shall regard this temperature as – 66° C. Our numerical results would be affected, but would only suffer a slight alteration, by substituting for this particular temperature any other which is admissible. It is, accordingly, legitimate to make our computation on this assumption, viz. that the temperature at Station E' is 66° C. below freezing point. At this temperature Clausius's formula, equation 1, gives for the velocity of least square in a gas

$$w = (111{\cdot}4)\sqrt{\frac{207}{\rho}},$$

$$= 1603 / \sqrt{\rho}, \qquad (5)$$

if we here use w to signify the velocity of least square at this particular temperature.

Let us next calculate a, the acceleration due to the attraction of the Earth at Station E (on the equator, and at the bottom of the atmosphere). Here

$$a = g + \gamma, \qquad (6)$$

where g is gravity at the equator, and γ the acceleration due to the Earth's rotation, *i.e.*

$$\gamma = \frac{u^2}{R} = \frac{(464\,\mathrm{II})^2}{6378\,\mathrm{V}},$$

$$= 3{\cdot}4 \text{ cm.} / \text{sec.} / \text{sec.}, \qquad (7)$$

where we use II for the two additional cyphers, and V for the five additional cyphers, which are necessary to express u and R in C.G.S. measure.*

Introducing this value of γ into equation 6, we find

$$a = g + \gamma = 978{\cdot}1 + 3{\cdot}4$$

$$= 981{\cdot}5 \text{ cm.}/\text{sec.}/\text{sec.} \qquad (8)$$

Again, $a = M/R^2$, where M, the mass of the Earth, is expressed in gravitation units, and K' (the potential at station E', which is at the top of the atmosphere) $= M/(R+h)$. Taking the ratio of these we get rid of M, so that it is immaterial in what units it has been expressed. We thus find

$$K' = a\frac{R^2}{R+h} = (981{\cdot}5)\frac{(6378\text{ V})^2}{6578\text{ V}},$$

$$= l^{-1}\, 11{\cdot}7830, \qquad (9)$$

where l^{-1} means "the number whose logarithm is." This result is expressed in C.G.S. measure.

Now $K' = v'^2/2$ (see equation 4), where v' is the minimum speed of projection which would carry a molecule clear away from the Earth, if the Earth were stationary. We thus find

$$v' = 1101500 \text{ cm.}/\text{sec.},$$

which is the same as

$$v' = 11{\cdot}015 \text{ km.}/\text{sec.} \qquad (10)$$

Now the rotation of the Earth carries station E' along at the rate of 0·478 km./sec. Hence a velocity

$$v' - u' = 11{\cdot}015 - 0{\cdot}478,$$

$$= 10{\cdot}537 \text{ km.}/\text{sec.},$$

will suffice, if the molecule be shot off in the direction in which it is already travelling in consequence of rotation. And, finally, if a strong west wind is blowing at station E', which must sometimes happen, a speed of

$$v' - u' - \alpha = 10{\cdot}5 \text{ km.}/\text{sec.} \qquad (11)$$

may be enough. This then we may take to be the least velocity which enables molecules to escape from the Earth.

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* The author has found it very convenient, especially in investigations touching on molecular physics, to use Roman figures to represent factors consisting of 1 followed by the number of cyphers indicated by the Roman figure. In this way VI means a million, XII means a billion; similarly, XXI means a uno-twentyone, which is about the number of gaseous molecules in each cubic centimetre of air at the bottom of our atmosphere.

Let us now turn to what happens in gas. By Clausius's formula, p. 310,

$$w \text{ (the velocity of mean square in a gas)} = (111{\cdot}4)\sqrt{\frac{T}{\rho}} \text{ m./sec.},$$

which, at 66° below zero (which we regard as the temperature at station E') gives

$$w = (111{\cdot}4)\sqrt{\frac{207}{\rho}},$$

$$= 1603 / \sqrt{\rho} \text{ m./sec.}, \qquad (12)$$

where w means the velocity of mean square in a gas at the temperature $-66°$ C.

If in this we put $\rho = 1$, we find

$$w = 1603 \text{ m./sec. in hydrogen.}$$

This is nearly a mile a second. Similarly putting $\rho = 2$, we find

$$w = 1133 \text{ m./sec., in helium,}$$

which is somewhat more than a kilometre per second. And, finally, if we put $\rho = 9$, we find

$$w = 534 \text{ m./sec., in the vapour of water,}$$

which is somewhat more than half a kilometre per second.

Now, we found above that, in order that any gas may cease to be imprisoned by the Earth, its molecules must now and then be able to attain at least a speed of 10·5 kilometres per second: see equation 11. Whenever this happens to a molecule favourably circumstanced it escapes. Hence, since hydrogen succeeds in leaking away from the Earth, its molecules must in sufficient numbers attain this speed, which is 6·55 times the velocity of mean square in that gas at a temperature 66° below zero; and since helium can escape, its molecules must sufficiently often reach a speed equal to or exceeding 9·27 times what we have found to be the velocity of mean square in helium at a temperature of $-66°$ C.

On the other hand, in order that a molecule of water may escape from the Earth, it has to get up a speed of 19·66, nearly twenty times the velocity of mean square in that vapour at the above temperature: and the fact that water does not drain away from the Earth in sensible quantities shows that this seldom happens.

We are now in a position to make a very important deduction in Molecular Physics from these facts, which is that *in a gas a molecular speed of* 9·27 *times the velocity of mean square is reached sufficiently often to have a marked effect upon the progress of events in nature*; while on the other hand a molecular speed of 20 times the velocity of mean square is an event which occurs so seldom that it exercises no appreciable influence over the cosmical phenomena which we have been considering. We must remember, however, that there are other events in nature—

in Chemistry, and especially in Biology—which may be, and probably are, determined by conditions that occur far more rarely.

The separation of the swiftest moving molecules from the boundary of our atmosphere is of necessity accompanied by a lowering *pro tanto* of the temperature of the atmosphere left behind. It is one of the many operations carried on by nature to which the Second Law of Thermodynamics does not apply. We must remember that this law is only a law of molecular averages, and therefore is not a law of nature where, as in this case, nature separates one class of molecules (those moving fastest) from the rest.

CHAPTER V.—*Extension of the Inquiry to other Bodies.*

In order to extend our inquiry to the atmospheres upon other bodies of the Solar system, we have to determine the potential of gravitation upon them. We can do this where r, the radius of the new body B, and m / M the ratio of its mass to the mass of the Earth, are known. For then

$$k \text{ (the potential at the surface of } B) = \frac{m}{r}$$

$$= \frac{m}{M} \cdot \frac{R+h}{r} \cdot \frac{M}{R+h}, \qquad (13)$$

of which the last factor is the K' which is given in a numerical form in equation (9)

Combining this with the dynamical equation (see p. 311)

$$k = v^2 / 2, \qquad (14)$$

we can calculate v, which would be the minimum velocity of escape from B, if B were at rest. In general B rotates, and then the minimum velocity of escape is

$$v' = v - u, \qquad (15)$$

where u, the velocity at the equator of B due to its rotation, is easily found, if we know from observation the period of rotation.

Having calculated v', we can determine what density a gas must have to escape from B with the same facility with which helium leaves the Earth. For this purpose, let w_1 be its velocity of mean square. Then, in accordance with what is stated on p. 314, w_1 may be as large as

$$w_1 = \frac{v'}{9{\cdot}27}, \qquad (16)$$

where w_1 and v' are to be expressed in metres per second: and then Clausius's equation, viz.

$$w_1 = (111{\cdot}4)\sqrt{\frac{T}{\rho_1}} \quad \text{m./sec.}, \qquad (17)$$

enables us to calculate ρ_1/T, *i.e.* the density of that gas which, at a specified temperature T, can escape from B as freely as helium does from the Earth at a temperature of – 66° C. This and all lighter gases will escape.

To determine what density of gas will be imprisoned by B as firmly as water is by the Earth, we proceed in a similar way. Here

$$w_2 = \frac{v'}{19{\cdot}66}, \tag{18}$$

and the rest of the work is the same as before, giving as its result the value of ρ_2/T, where ρ_2 is the density of a gas which will find it as difficult to escape from B as water does from the Earth. It and all denser gases will be retained.

The investigation leaves uncertain the fate of gases whose density lies between ρ_1 and ρ_2.

CHAPTER VI.—*Of the Moon.*

When we turn to the Moon, we find the conditions to be such that it can rid itself of an atmosphere with much ease. Upon the Moon

r (its radius), ... = 1738 km.

$\frac{m}{M}$ (the ratio of its mass to that of the Earth), . = 0·01235

P (its period of rotation), ... = 2,360,591 seconds.

Calculating v', the least velocity which would enable a missile to quit the Moon by the equations in the last chapter, we find it to be about 2·38 km./sec., while on the Earth it is 11·015 km./sec., which, by the help of the rotation of the Earth and possible storm, may be, under favourable circumstances, furnished by a relative projectile velocity of 10·5 km./sec. Accordingly, more massive molecules can disengage themselves from the Moon with the same facility with which helium can leave the Earth, if ρ, their molecular mass, is greater than that of helium, in the ratio of the square of 10·5 to the square of 2·38, *i.e.* if the molecules are 19·5 times heavier than those of helium, or, which is the same thing, 39 times heavier than those of hydrogen. Accordingly, hydrogen sulphide, with a molecular mass 17 times that of hydrogen, oxygen with a molecular mass of 16, nitrogen with a molecular mass of 14, and the vapour of water with a molecular mass of 9, will hurry away. They will all escape with greater facility than hydrogen does from the Earth. A like fate will befall argon with a molecular mass of 20, carbon dioxide with its molecular mass of 22, carbon disulphide with its molecular mass of 38, and all others of the gases emitted by volcanoes, or from fissures, of which the vapour density is less than 39. These will escape with greater promptness than does helium from the Earth.

This is what would happen if the Moon were by itself, and if portions of its surface could rise even to a temperature of – 66° C. But the conditions are more favourable. Lord Rosse infers from his observations that the temperature of the Moon's surface rises something like 280° C. when exposed to the fierce glare of the Sun's rays. Even if it shall turn out that this is an overestimate, it at all events makes it probable that the maximum temperature is very much higher than 207° above the absolute zero, which is the same as 66° below the freezing point. Moreover the proximity of the Earth would somewhat assist the process at its present distance; and its greater proximity in former ages must have more assisted it. In fact, on this account, any of the gases or vapours in question which had been developed upon the Moon while the Moon was close to the Earth must have been for the most part transferred over to the Earth, if the Earth was then cool enough to retain them. Those molecules that have escaped from the Moon since its distance from the Earth became considerable have for the most part become independent planets travelling in a ring round the Sun, of which ring (roughly speaking) the Earth's path is the central line. There they are accompanied by most of the molecules of hydrogen and helium that have leaked away from the Earth. A very few of the latter which happened to be shot off at unusually high speed, and in the direction towards which the Earth was at the time travelling in its orbit, may have been able to disengage themselves altogether from the Solar system; but this can have happened to but few of those thrown off from the Earth, and not to almost any of those ejected from the Moon.

CHAPTER VII.—*Of Mercury.*

The radius of Mercury may be obtained by assuming the equatorial radius of the Earth to be 6378 kilometres, and applying to it the data given in the preface to the *Nautical Almanac* for 1899. We thus find the planet's radius

$$r = \frac{3''\cdot 34}{8''\cdot 848}\,6378 = 2406 \text{ km.}$$

The mass of Mercury is less satisfactorily known. We shall use the value

$$\frac{m}{M} = 0\cdot 065.$$

Mercury's rotation period is also in doubt. The difficult observations that have hitherto been made seem to be about equally consistent with a rotation period of nearly a day, and a rotation period of 88 days (the period of Mercury's revolution round the Sun). Possibly observations could be made in the daytime which would determine between these. Meanwhile

$$u = 2 \text{ m.} / \text{sec., if the rotation period is 88 days,}$$

$$u = 175 \text{ m.} / \text{sec., if the rotation period is 1 day.}$$

By using the above values for r and m / M in equations 13 and 14, we find

v (the minimum velocity of escape, if Mercury were at rest) $= 4643$ m. / sec.,

which is a little more than $4\frac{1}{2}$ km. / sec. Hence

$$v' = v - u = 4641 \text{ m.} / \text{sec., if the rotation period is 88 days,}$$

and

$$= 4468 \text{ m.} / \text{sec., if the rotation period is 1 day.}$$

By employing these values in equations 16 and 17, we find that

ρ (the density of the gas that will escape from Mercury, as freely as helium does from the Earth) . . . = 10·25, on the 88-day hypothesis,

and = 11, on the 1-day hypothesis,

and on the further supposition that the absolute temperature of the gas where it escapes is 207, that is, 66° C. below zero.

If the highest temperature at the upper surface of Mercury's atmosphere over his equator is higher than this, and it is probably much higher, the foregoing values for ρ will have to be increased in the ratio of $T / 207$, where T is the highest temperature reached. It must also be remembered that helium is so prompt in escaping from the Earth that it is probable that gases somewhat denser could escape; and, as a consequence, that the limiting density of the gases that can escape from Mercury has to be increased in the same proportion.

The general conclusion then is—

1. That water with a density of 9 certainly cannot exist upon Mercury. Its molecules would very promptly fly away.
2. That it is in some degree probable that both nitrogen and oxygen, with densities of 14 and 16, would more gradually escape.

It is, therefore, not likely that there are, in whatever atmosphere Mercury may be able to retain, any of the constituents of the Earth's atmosphere except perhaps argon and carbon dioxide.

CHAPTER VIII.—*Of Venus.*

The state of Venus's atmosphere need not detain us long. The potential of gravitation is so nearly the same on this planet as on the Earth that its atmosphere almost certainly retains and dismisses the same gases as does the atmosphere of the Earth. The only element of uncertainty arises from its period of rotation being imperfectly known, but the nearly globular form of the planet assures us that its rotation cannot be swift enough seriously to affect the problem.

The similarity of the two atmospheres is confirmed by the appearance of the planet. Venus is presumably a much younger planet than the Earth, and its temperature is consequently what the Earth's was many ages ago, when through excessive evaporation water was the largest constituent of our atmosphere, and when clouds were present everywhere and without intermission.

The conditions upon Venus are so nearly akin to those on the Earth that we cannot be mistaken in regarding the vapour which forms the abundant cloud we see on that planet as none other than the vapour of water. If we may assume this, we can advance a step farther than the statements made in Chapter IV.

The detailed computations in the case of Venus give

$$r = \frac{8''{\cdot}40}{8''{\cdot}848}\,6378 = 6053 \text{ kilometres},$$

$$\frac{m}{M} = 0{\cdot}769\,;$$

and as such observations as are practicable seem to indicate that on that planet

$$P = 83779 \text{ seconds},$$

we find that

$$v = 10000 \text{ m./sec.},$$

$$u = 454 \text{ m./sec.};$$

whence we infer that

$$v' = v - u = 9546 \text{ m./sec.}$$

is the least speed which will carry a projectile away from Venus.

Now, in water, $\rho = 9$. Whence, in accordance with Clausius's formula, p. 310, the velocity of mean square in water, at the temperature of $-66°$ C., is

$$w = \frac{1603}{\sqrt{\rho}} = 534 \quad \text{m./sec.}$$

Now v' is almost exactly 18 times this value of w; so that the circumstance that Venus is able to retain its hold upon water means that the molecules of a gas do not attain a velocity 18 times that of mean square sufficiently often to enable the gas to escape from an atmosphere in appreciable quantities.

We are accordingly now in a position to go beyond the statement made on p. 314. We may now say—

1°. A velocity of 9·27 times that of mean square is attained by the molecules of a gas sufficiently often to enable helium to escape from the Earth.

2°. A velocity 18 times that of mean square is so seldom attained that Venus has been able to retain its stock of water.

3°. Since Venus can prevent the escape of water, the Earth, with its larger potential, is competent to retain its hold upon a gas of somewhat less density, viz., one whose density $\rho = 7{\cdot}43$.

Accordingly, as regards the Earth, we may come to the following conclusions: 1°, Gases with a density of 2 or less than 2 can certainly escape from the Earth; 2°, a gas with a density of 7·43, and all denser gases* are effectually imprisoned by the Earth; 3°, the information supplied by Venus, supplemented by our present chemical knowledge, does not determine what would be the fate of a gas, if there be such, whose density lies between 2 and 7·43.

CHAPTER IX.—*Of Mars.*

The case of Mars is one of exceptional interest. Using the data furnished by the *Nautical Almanac*, we find its radius to be

$$r = 3372 \text{ km.}$$

As in the case of Mercury, its mass is not yet known with exactness. It has become better known since observations have been made on the elongations of its satellites, which seem to furnish the value

$$\frac{m}{M} = 0{\cdot}1074.$$

Its period of rotation is known, viz.: 88643 seconds; whence and from its radius we find

$$u \text{ (the velocity at the equator due to rotation)} = 239 \text{ m./sec.}$$

---

* Ammonia NH_3, and Methane CH_4, are a little above this limit, and therefore can neither of them escape. Ammonia is no doubt washed out of the Earth's atmosphere by rain; but it is not easy to see what becomes of the methane. It seems unlikely on chemical grounds that it directly combines with oxygen, furnishing water and carbon dioxide. Possibly it meets with a trace of chlorine, and furnishes methyl chloride and hydrogen in the presence of sunshine; or possibly it is nitro-methane that is formed.

By following the same steps as in the case of Mercury, we find successively

$$v = 5042 \text{ m./sec.}$$

for the least velocity which would carry a missile away from Mars, if Mars were not rotating, and

$$v' = v - u = 4803 \text{ m./sec.}$$

for the relative velocity which is sufficient in consequence of the rotation.

From this, and equations 16 and 17, we find

$$\rho = 9{\cdot}57$$

as the density of a gas which would escape from Mars at a temperature of $-66°$ C., with the same facility as helium from the Earth.

We must here make some allowance for the probability that the highest temperature at which a gas has an opportunity of escaping from Mars may be lower than the corresponding temperature on the Earth. And we must, on the other hand, remember that the molecules of helium are almost certainly not quite the heaviest molecules that can rid themselves of the Earth. Taking both considerations into account, *it is legitimate to infer that water, in which* $\rho = 9$, *cannot remain on Mars.*

As to what happens to gases with densities of 14 and 16, we cannot speak with confidence. They may perhaps be imprisoned. And the conspicuous polar snows of Mars make it in a considerable degree probable that carbon dioxide, of which $\rho = 22$, is abundantly present.

It appears here to be worth reviewing the state of things that must prevail if the atmosphere of Mars consist mainly of nitrogen and carbon dioxide. Without water, there can be no vegetation upon Mars, at least not such vegetation as we know; and, in the absence of vegetation, it is not likely that there is much free oxygen. Under these circumstances, the analogy of the Earth suggests that the atmosphere of Mars consists mainly of nitrogen, argon, and carbon dioxide.

Carbon dioxide, the most condensible gas of such an atmosphere, would behave very differently from the way in which water behaves on the Earth. Water in the state of vapour is so much lighter than the other constituents of our atmosphere that it hastens upwards through the atmosphere; and, accordingly, its condensation into cloud, whether of droplets of water or spicules of ice, takes place usually at very sensible elevations. There would be no such hurry to rise; there would, on the contrary, be great sluggishness in the diffusing upwards of carbon dioxide through an atmosphere of nitrogen. When brought to the ground in the form of snow or frost (for there would probably be no rain), and when subsequently evaporated, the carbon dioxide gas would crawl along the surface, descending into valleys, occupying plains and pushing its way under the nitrogen, mixing only slowly with the nitrogen; and, as a result, only a very small proportion of the whole stock would be at any one time found elsewhere in the atmosphere than near the ground. It is suggested that the fogs, the snows, the frosts, and the evaporation of such a constituent of the atmosphere may account for the peculiar and varying appearances upon Mars, which, though recorded in our maps as if they were definite, are in reality very imperfectly seen from our distant Earth. In fact Mars, when nearest the Earth, which unfortunately seldom happens, is still 140 times farther off than the Moon. Fogs over the low-lying plains which on Mars correspond to the bed of our ocean, with mountain chains projecting through the fog, and a border of frost along either flank of these ranges, would perhaps account for some of the appearances which have been glimpsed; and extensive displacements of the vapour, consequent upon its distillation towards the two poles alternately, would perhaps account for the rest.

CHAPTER X.—*Of Jupiter.*

In the case of the planet Jupiter, we have the following data:—

$$r \text{ (Jupiter's equatorial radius)} = \frac{97''\cdot 36}{8''\cdot 848}\,6378 = 70170 \text{ km.},$$

$$P \text{ (the periodic time of his rotation)} = 35{,}728 \text{ seconds},$$

$$\frac{m}{M} \text{ (m being Jupiter's mass, and M the mass of the Earth)} = 311\cdot 9.$$

Using these data we find—

u (the velocity at his equator, owing to the rotation) $= 12\cdot 337$ km./sec.

v (the least velocity which would carry a missile away, if Jupiter were not rotating) $= 59\cdot 570$ km./sec.

$v' = v - u$ (the least velocity which enables a missile to escape when helped by the rotation) $= 47\cdot 233$ km./sec.

ρ_1 (the density of gas which would escape from Jupiter, at a temperature of $-66°$ C., with as much ease as helium does from the Earth) $= 0\cdot 099$ of the density of hydrogen.

ρ_2 (the density of a gas which would be imprisoned by Jupiter as effectually as water is by Venus) $= 0\cdot 373$ of the density of hydrogen.

Hence gases with a density less than 1/10 of that of hydrogen (if any such exist) could escape from Jupiter. But Jupiter can prevent the escape of a gas which has a density a little more than a third of the density of hydrogen, and of all denser gases.

Jupiter is accordingly able to imprison all gases known to chemists. His atmosphere may therefore, so far as can be determined by the present inquiry, have in it all the constituents of the Earth's atmosphere, with the addition of helium and hydrogen, and any elements between hydrogen and lithium which the Earth may have lost; except that, if the hydrogen is sufficiently abundant, there can be no free oxygen. Owing to the chemical reaction that would then take place, the oxygen will have been used up in adding to the stock of water.

CHAPTER XI.—*Of Saturn, Uranus, and Neptune.*

Our information with reference to these three planets is less satisfactory. Computing their radii from the data given in the *Nautical Almanac*, we find

$$
\begin{aligned}
r &= 61060 \text{ km. on Saturn,} \\
&= 24700 \text{ km. on Uranus,} \\
&= 26340 \text{ km. on Neptune.}
\end{aligned}
$$

Their masses compared with the masses of the Earth are also sufficiently known, viz.:

$$
\begin{aligned}
m/M &= 93{\cdot}328, \text{ for Saturn,} \\
&= 14{\cdot}460, \text{ for Uranus,} \\
&= 16{\cdot}863, \text{ for Neptune;}
\end{aligned}
$$

but their rotation periods are very imperfectly known. We shall take them to be about

$$
\begin{aligned}
P &= 36864 \text{ seconds, of Saturn,} \\
&= 36000 \text{ seconds, of Uranus,} \\
&= 36000 \text{ seconds, of Neptune.}
\end{aligned}
$$

If we may use these values, we find

$$
\begin{aligned}
u &= 10{\cdot}412 \text{ km./sec., on Saturn,} \\
&= 4{\cdot}311 \text{ km./sec., on Uranus,} \\
&= 4{\cdot}598 \text{ km./sec., on Neptune,}
\end{aligned}
$$

for the velocity at the equator due to the planet's rotation. Further, by equations

13 and 14, we find for the minimum velocity of escape from each of these planets, if not rotating,

$$\begin{aligned} v &= 34{\cdot}92 \text{ km. / sec., on Saturn,} \\ &= 21{\cdot}61 \text{ km. / sec., on Uranus,} \\ &= 22{\cdot}60 \text{ km. / sec., on Neptune;} \end{aligned}$$

whence

$$\begin{aligned} v' = v - u &= 24{\cdot}508, \text{ on Saturn,} \\ &= 17{\cdot}299, \text{ on Uranus,} \\ &= 18{\cdot}002, \text{ on Neptune,} \end{aligned}$$

is the least velocity which enables a missile to escape when helped by the rotation.

By dividing these last numbers by 9·27, we find the velocity of mean square of the gas which can escape as freely as does helium from the Earth, and then by Clausius's formula, we can calculate ρ_1, its density, which is

$$\begin{aligned} \rho_1 &= 0{\cdot}37 \text{ of the density of hydrogen on Saturn,} \\ &= 0{\cdot}74 \text{ of the density of hydrogen on Uranus,} \\ &= 0{\cdot}68 \text{ of the density of hydrogen on Neptune.} \end{aligned}$$

On the other hand, by dividing the values for v' by 18, we learn what is the velocity of mean square of the gas which would be detained as firmly as water is held by Venus; and then, if we calculate ρ_2 by Clausius's formula, we find

$$\begin{aligned} \rho_2 &= 1{\cdot}39 \text{ times the density of hydrogen on Saturn,} \\ &= 2{\cdot}78 \text{ times the density of hydrogen on Uranus,} \\ &= 2{\cdot}57 \text{ times the density of hydrogen on Neptune.} \end{aligned}$$

Now hydrogen, with a density of 1, stands in each case between ρ_1 and ρ_2, and we are, therefore, left uninformed whether hydrogen is or is not allowed to escape. There is, perhaps, some ground for conjecturing that it cannot escape from Saturn, and that it can escape from Uranus and Neptune. But this must remain doubtful. Helium, with its density of 2, being more than the value of ρ_2 upon Saturn, is certainly imprisoned by that planet, but we have no satisfactory information as to what is its fate upon Uranus or Neptune.

Thus the information we gain with reference to these three planets amounts to this—that we have no definite information as regards hydrogen; that Saturn is able to detain helium, but that we do not know whether the other two planets can or cannot; that all other gases known to chemists would be more firmly imprisoned by any one of these planets than they are by the Earth; and that, if there be gases lighter than hydrogen, it is certain that Saturn cannot detain any of which the density falls as low as one-third of that of hydrogen, Neptune cannot hold any as light as two-thirds, nor Uranus any lighter than three-quarters of the density of hydrogen. On the whole, the probability seems to be that the atmosphere of Saturn is nearly the same as that of Jupiter; while the atmospheres of Uranus and Neptune more nearly approximate to that of the Earth, with perhaps the addition of any gases with densities less than 7·34 that may possibly have left the Earth when the Earth was hotter, and whose withdrawal from the Earth is perhaps what has left the gaps in the series of terrestrial elements which appear to exist between hydrogen and helium, and between helium and lithium.

CHAPTER XII.—*Of the Satellites and Minor Planets.*

We have no sufficient information as to the densities of any of these bodies. But the asteroids, or minor planets, which lie between the orbits of Mars and Jupiter, are all of them bodies so small that, even if they were as dense as osmium, iridium, or platinum, they could not retain their hold upon an atmosphere. The same may be said of the two satellites of Mars, of the new satellite of Jupiter, of most of the satellites of Saturn, and of the small bodies that make up the rings of Saturn. None of these can condense any atmosphere upon them. If there are molecules of gases travelling in their neighbourhood, they also are, each of them, an independent satellite.

One satellite of Saturn and three of Jupiter are larger than our Moon; and one other of Saturn and one of Jupiter, though smaller than the Moon, are not much smaller. We should need to know the densities of these bodies before we could speak with confidence about them. The presumption, however, is, that as their primaries are very much less dense than the Earth, so these satellites are probably less dense than the Moon. If so, they also, as well as the smaller satellites, must be devoid of atmosphere.

We know too little about the satellites of Uranus and Neptune to venture upon any conclusion about them. The satellite of Neptune appears to be a body of considerable size, and, with some probability, it may have an atmosphere.

CHAPTER XIII.—*What becomes of the Molecules that escape.*

The speed of the Earth in its orbit is about 30 km./sec. Now it follows, from the dynamics of potential, that the potential of the Sun at the distance of the Earth is represented by the square of this number if the Sun's mass be measured in gravitational units. That is

$$k = \frac{m}{r} = 900,$$

where m is the mass of the Sun, and r the radius of the Earth's orbit.

We have already found, on p. 313, the potential of the Earth at the boundary of our atmosphere to be

$$K' = \frac{M}{R+h} = \frac{v'^2}{2} = \frac{121}{2} = 60{\cdot}5.$$

Therefore the joint potential of the Sun and Earth at that station is

$$\frac{m}{r} + \frac{M}{R+h} = 960{\cdot}5.$$

This, then, is equal to $v^2/2$, when v is the least velocity which would enable a missile to escape from both these bodies. Therefore

$$v = \sqrt{(2 \times 960{\cdot}5)} = 43{\cdot}83 \text{ km./sec.}$$

If the missile be shot off in the direction towards which the Earth is travelling, it has already got, in common with the rest of the Earth, 30 km./sec. of this velocity; and therefore, if fired off in that direction, the speed with which it would need to part from the Earth is 13·83 km./sec. Now, as 11 km./sec. is enough to enable a molecule to leave our atmosphere, it can be but very seldom that a molecule quits it with a speed of 13·83 km./sec.; and, accordingly, nearly all the molecules that have left the Earth have remained in the Solar system, and are in fact now travelling as independent planets round the Sun.

We have taken the special case of a molecule leaving the Earth's atmosphere. A similar treatment applies to molecules leaving the atmospheres of other planets and satellites. In every case the velocity required to enable a molecule to quit the Solar system is markedly in excess of that which enables it to escape from its own atmosphere. Accordingly, almost all such wandering molecules are still denizens of the Solar system.

CHAPTER XIV.—*Former size of the Sun.*

The Sun is contracting, and therefore in past time was larger than it now is. The question then arises, how much larger may it have been while it was still globular? We can place a limit on its possible size *if we assume that it was then, as now, able to prevent the escape of free hydrogen*, and if we assign a temperature below which its outer boundary did not fall.

In order to arrive at definite results, let us suppose this temperature to be 0° C. Here we might take into consideration the probability that, at a sufficiently remote period, the planets formed part of the Sun. But it is needless to do this, as the addition to be then made to its present mass would be only about 1/750th part, which is too slight an increase sensibly to affect our present computation.

We have first to ascertain what the "velocity of mean square" of hydrogen is at the freezing temperature. It is got by putting $T = 273$ and $\rho = 1$ into Clausius's formula, page 310. We thus find $w = 1\cdot841$ km./sec. This multiplied by 9·27 (see page 314) gives us a velocity v_1 which the molecules of hydrogen could, at this temperature, get up sufficiently frequently, for the purposes of escape. And if multiplied by 18 (see page 320), it furnishes a velocity v_2 which hydrogen is unable to get up sufficiently frequently for effective escape. We thus find

$$v_1 = 17 \text{ km./sec.} \qquad v_2 = 33\cdot14 \text{ km./sec.}$$

We have next to find how large the Sun should be in order that one or other of these velocities should be that which is just sufficient for the escape of a molecule. For that, r_1 and r_2 being the corresponding radii, the potentials must amount to

$$m \quad 17^2 \qquad\qquad m \quad (33\cdot14)^2$$

ERRATA.

Page 326, line 7, *after* "both these bodies" *add* "if stationary."

„ „ **line 12,** *after* "13·83 km./sec." *add the following* :—

> Accordingly this is a velocity which would suffice to set the molecule completely free, if the Earth were arrested in its orbit immediately after the molecule left it. But since, on the contrary, the Earth persists on its course, a slightly greater speed of projection is actually needed.

„ „ **line 14,** *change* "with a speed of" *into* "with a velocity somewhat exceeding."

In carrying on an inquiry such as that of the present Memoir, we should keep in mind that the encounters between molecules have not the same effect on their subsequent motions as mere collisions between elastic or partially elastic solids would have. Let us, for simplicity, picture to ourselves two molecules which approach one another along a straight line, and after an encounter, which is in fact a complex struggle, recede from one another along the same line.

If they were solid particles with elasticity e, the equations of their motion would be

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2\,,$$

$$u_1 - u_2 + e\,(v_1 - v_2) = 0\,,$$

where v_1v_2 are the velocities before, and u_1u_2 the velocities after, the collision, We have already found, on p. 313, the potential of the Earth at the boundary of our atmosphere to be

$$K' = \frac{M}{R + h} = \frac{v'^2}{2} = \frac{121}{2} = 60{\cdot}5.$$

Therefore the joint potential of the Sun and Earth at that station is

$$\frac{m}{r} + \frac{M}{R + h} = 960{\cdot}5.$$

This, then, is equal to $v^2/2$, when v is the least velocity which would enable a missile to escape from both these bodies. Therefore

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The Sun is contracting, and therefore in past time was larger than it now is. The question then arises, how much larger may it have been while it was still globular? We can place a limit on its possible size *if we assume that it was then, as now, able to prevent the escape of free hydrogen*, and if we assign a temperature below which its outer boundary did not fall.

In order to arrive at definite results, let us suppose this temperature to be 0° C. Here we might take into consideration the probability that, at a sufficiently remote period, the planets formed part of the Sun. But it is needless to do this, as the addition to be then made to its present mass would be only about 1/750th part, which is too slight an increase sensibly to affect our present computation.

We have first to ascertain what the "velocity of mean square" of hydrogen is at the freezing temperature. It is got by putting $T = 273$ and $\rho = 1$ into Clausius's formula, page 310. We thus find $w = 1{\cdot}841$ km./sec. This multiplied by 9·27 (see page 314) gives us a velocity v_1 which the molecules of hydrogen could, at this temperature, get up sufficiently frequently, for the purposes of escape. And if multiplied by 18 (see page 320), it furnishes a velocity v_2 which hydrogen is unable to get up sufficiently frequently for effective escape. We thus find

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We have next to find how large the Sun should be in order that one or other of these velocities should be that which is just sufficient for the escape of a molecule. For that, r_1 and r_2 being the corresponding radii, the potentials must amount to

$$\frac{m}{r_1} = \frac{17^2}{2} = 144{\cdot}5, \qquad \frac{m}{r_2} = \frac{(33{\cdot}14)^2}{2} = 549.$$

But at the distance of the Earth we found $m/r = 900$. Therefore

$$\frac{r_1}{r} = \frac{900}{144{\cdot}5} = 6{\cdot}227, \qquad \frac{r_2}{r} = \frac{900}{549} = 1{\cdot}64.$$

That is, the surface of the Sun would need to have been about $6\frac{1}{4}$ times farther from the Sun than the Earth now is, in order that hydrogen at 0° C. should escape from it as freely as helium does from the Earth at – 66° C. And it would need to have been 1·64 times farther than the Earth to imprison the hydrogen as firmly as water is held by Venus.

Hence, the *greatest* size which the Sun can have had since it became a sphere, consistently with its not allowing hydrogen at 0° C. to escape, is an immense globe extending to some situation intermediate between the orbits of Mars and Jupiter. From some such vast size it may have been ever since slowly contracting.

CHAPTER XV.—*Of Motions in a Gas.*

In carrying on an inquiry such as that of the present Memoir, we should keep in mind that the encounters between molecules have not the same effect on their subsequent motions as mere collisions between elastic or partially elastic solids would have. Let us, for simplicity, picture to ourselves two molecules which approach one another along a straight line, and after an encounter, which is in fact a complex struggle, recede from one another along the same line.

If they were solid particles with elasticity e, the equations of their motion would be

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2,$$
$$u_1 - u_2 + e(v_1 - v_2) = 0,$$

where v_1v_2 are the velocities before, and u_1u_2 the velocities after, the collision, and where e, the coefficient of elasticity, depends on the amount of the kinetic energy which is expended on internal events during the collision. It is therefore necessarily a proper fraction; so that e, in the case of solid particles, cannot exceed 1, whereas, in the encounters between molecules, it may have any value whether above or below 1. This is because, during an encounter between molecules, energy is in some cases imparted to, and in other cases withdrawn from, the motions of the molecules along their free paths, whereas, in a mere collision, energy is always withdrawn. In fact, the *internal* events of individual molecules are in communication with heat motions in the æther, and interchange energy with it. A molecule may thus absorb energy from the æther during the whole of the long flights which it makes, when near the top of an atmosphere, between its encounters; and any excess of energy thus acquired will be shared with the motions of translation of the molecules when the next encounter takes place. Accordingly, the value of e will vary from one encounter to another, and, near the boundary of an atmosphere, there may be changes in the velocities of the molecules which are more abrupt than in situations where the gas is denser.

The effect here spoken of would be more marked in the case of helium, water, nitrogen, or oxygen, than in that of hydrogen, inasmuch as solar rays of the kind that hydrogen can absorb reach the Earth in a feebler state than those which the other gases absorb, owing to the partial absorption by hydrogen which has already taken place in the hot outer atmosphere of the Sun. On this account the rays that can affect hydrogen are the relatively feeble radiations from Fraunhofer lines, whereas the molecules of the other gases are exposed on the confines of our atmosphere to the glare of full sunshine. This is evidenced by the Earth-lines of the solar spectrum, especially those due to oxygen and aqueous vapour.

These considerations were taken into account in fixing on – 66° C. as the maximum temperature to be attributed to the outer layer of our atmosphere. No doubt it would, in some slight degree, improve the investigation to use a rather lower temperature in the solitary case of hydrogen; but it was not thought necessary to make a distinction of this kind in an investigation which, from the nature of the case, could only be approximate. The only effect of introducing the refinement would have been to show that the facility with which hydrogen escapes from an atmosphere is not quite so much in excess of the facility with which helium escapes as the numbers in Chapter IV. indicate. This is almost certainly true to some small extent; but it leaves our main conclusions undisturbed. Accordingly, the simpler mode of inquiry, in which these and other small differences are ignored, has been an adequate investigation for our purpose.

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XIV.

JAMAICAN ACTINIARIA. Part I.—ZOANTHEÆ.

By J. E. DUERDEN,
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(Plates XVII. a, XVIII. a, XIX., XX.)

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[Read MARCH 24, 1897.]

THE following account, restricted to the well-defined group of the Zoantheæ, is a first contribution from investigations now being carried out upon the Jamaican Actiniaria. It is remarkable that, with the exception of two species of Palythoa, collected by Sir Hans Sloane, probably about the year 1687, no Actinian has, so far as I can ascertain, been recorded from the island. Thanks to the labours of MM. Duchassaing and Michelotti (1850, 1860, 1866), and to the later researches of Professor M^c^Murrich (1889, 1889 *a*, 1896), we are acquainted with numerous examples from the other West Indian Islands, with which the Jamaican forms may be compared. These are proving that the Actinian fauna of the whole Caribbean region presents no marked difference. Professor M^c^Murrich has shown this for the Bahamas and the Bermudas, and of thirty-four Jamaican species now known, nearly all are forms recorded from one or more of the other islands of the Antilles. With the exception of the valuable work contributed by M^c^Murrich, practically no studies on Western forms have been conducted along the modern anatomical lines instituted and carried out elsewhere by Hertwig, Erdmann, Haddon, and others. Hence the necessity that the different representatives, many only partially known, should be submitted to microscopical examination to enable them to be arranged in the later systems of classification.

The following definition of the group of the Zoantheæ is the one given by Professor Haddon and Miss Shackleton (1891), and is practically the same as that accepted by all recent writers:—

ZOANTHEÆ.

Actiniæ with numerous perfect and imperfect mesenteries, and two pairs of directive mesenteries, of which the sulcar are perfect and the sulcular are imperfect. A pair of mesenteries occurs on each side of the sulcular directives, of which the sulcular moiety is perfect and its sulcar complement is imperfect; a similar second pair occurs in one section of the group (Brachycneminæ), or the second pair may be composed of two perfect mesenteries (Macrocneminæ). In the remaining pairs of mesenteries, of both divisions, this order is reversed, so that the perfect mesentery is sulcar and the imperfect is sulcular. The latter series of mesenteries are bilateral as regards the polyp, and arise independently (*i.e.* neither in pairs nor symmetrically on each side) in the exocœle on each side of the sulcar directives, in such a manner that the sulcular are the oldest and the sulcar the youngest. Only the perfect mesenteries are fertile or bear mesenterial filaments. A single sulcar œsophageal groove is present. The mesoglœa of the body-wall is traversed by irregularly branching ectodermal canals or by scattered groups of cells. The body-wall is usually incrusted with foreign particles. The polyps are generally grouped in colonies connected by a cœnenchyme, the cœlenteron of each polyp communicating with that of the other members of the colony by means of basal endodermal canals.

Family. ZOANTHIDÆ, DANA, 1846.

(With the definition of the Group.)

Sub-family. BRACHYCNEMINÆ, Hadd. and Shackl., 1891.

Zoantheæ in which the sulcar element of the primitive sulco-lateral pair of mesenteries is imperfect.

GENERA.

Zoanthus, Lamarck, 1801.
Isaurus, Gray, 1828.
Gemmaria, Duchassaing and Michelotti, 1860.
Palythoa, Lamouroux, 1816.
Sphenopus, Steenstrup, 1856. (Not represented in the West Indian collections.)

Sub-family. MACROCNEMINÆ, Hadd. and Shackl., 1891.

Zoantheæ in which the sulcar element of the primitive sulco-lateral pair of mesenteries is perfect.

GENERA.

Epizoanthus, Gray, 1867.
Parazoanthus, Haddon and Shackleton, 1891.

One of the two type species of the genus Mammillifera, established by Lesueur, having been shown by McMurrich (1896) to possess all the characters of a Zoanthus, and there being every probability that the other type species, when discovered, will have the same, this genus, formerly included in the Zoanthidæ, can no longer be recognized (see p. 334).

With the exception of an irregular arrangement of the mesenteries in the genera Gemmaria and Palythoa, referred to below, nothing of importance has occurred differing from the diagnoses, mainly anatomical, of the tribe and genera given in the works of the writers referred to above.

Since the arrangement of the mesenteries in the Zoantheæ, which differs from that met with in all other Actiniaria, was first fully elucidated, it has also been recognized that the group presents a further distinction into two sub-divisions dependent upon the nature of the second pair of mesenteries on each side of the sulcular directives, according as the pair consists of a perfect and imperfect mesentery, or of two perfect mesenteries. The former was first termed by Dr. Erdmann the "microtypus," and the latter the "macrotypus"; a distinction emphasized later by Haddon and Shackleton (1891) in the formation of the two sub-families Brachycneminæ and Macrocneminæ. Apparently no variation from these two seemingly well-fixed divisions has since been noted. It is therefore interesting to find that, in West Indian species of the genus Gemmaria and of Palythoa, an irregular condition has been met with. In *Gemmaria variabilis*, n. sp., a specimen sectionized showed the normal brachycnemic arrangement on one side and the macrocnemic on the other. In a colony of *Palythoa mammillosa*, Ell. and Sol., one polyp was normally brachycnemic on the right, but macrocnemic on the left side; and in another polyp, in the same colony, the brachycnemic condition was on the left side and the macrocnemic on the right (Pl. XIX. A, figs. 2 and 3). Similar combinations exist in *Palythoa caribæa*, Duch. and Mich.; but one polyp exhibited the full macrocnemic arrangement on both sides, in place of the normal brachycnemic (Pl. XIX., fig. 7).

It is thus clear that in these three species, at least, the fundamental distinction of the microtype and macrotype is not sufficiently fixed, so that both may appear in one colony, or even on opposite sides in the same individual. In a number of specimens examined the majority are, however, normal.

In the present communication the following ten species are described:—

ZOANTHEÆ.

BRACHYCNEMINÆ.

Zoanthus Solanderi, Lesueur.
Zoanthus flos-marinus, Duchassaing and Michelotti.
Zoanthus pulchellus (Duchassaing and Michelotti).
Isaurus Duchassaingi (Andres).
Gemmaria variabilis, n. sp.
Gemmaria fusca, n. sp.
Palythoa mammillosa (Ellis and Solander).
Palythoa caribæa, Duchassaing and Michelotti.

ZOANTHEÆ (*continued*).

Macrocneminæ.

Epizoanthus minutus, n. sp.
Parazoanthus Swiftii (Duchassaing and Michelotti).

All the examples having been partially studied in their living condition, and generally from an abundant supply of material, it has not been possible in some cases to draw up the specific characters in very hard and fast terms. The few external features one has to depend upon in the Zoanthidæ are well known to all workers in the group to be very variable; and especially will this be seen to be the case in the genera Zoanthus and Palythoa.

Recognizing the form of the sphincter muscle as of great importance in specific identification, I have figured it in all cases.

Practically all the material has been preserved by simple immersion in a four or five per cent. solution of formalin. Owing to the presence of abundant incrustations and the great thickness of the mesoglœa, the internal tissues of the Zoanthidæ are rarely well preserved. It is satisfactory to find that, by means of formalin, the preservation and histology was, in every case, all that could be desired, while, in most, little alteration of form or dimensions occurred; thus allowing the number of capitular ridges and tentacles, measurements, etc., to be taken at leisure. The colours can likewise be observed for some time, but disappear ultimately.

A curious chromatic change occurred in most of the Palythoa material. The colonies, usually cream colour when alive, became strongly brick-red in their upper region after immersion for a short time in the formalin. This alteration extended also to the ectoderm of the œsophagus and to the mesenterial filaments.

Some importance must be attached to the method of preservation in determining the appearance of the various histological characters. With alcohol the mesoglœa shrinks very considerably. To this disproportionate shrinkage, compared with that of the ectoderm and cuticle, is due the contorted or dendriform appearance of the outer part of the body-wall often seen in species of Zoanthus. The size and appearance of the mesoglœal cavities, especially those containing the sphincter muscle, may be much modified. Figs. 1, 2, and 3, on Pl. xviii. a, should be compared. The last having narrow, almost closed cavities, was drawn from a polyp shrunk in alcohol, and the two first from colonies preserved without shrinkage in formalin. Specimens of *Z. pulchellus* preserved later in formalin show open cavities like figs. 1 and 2. The figure of the cavities of the sphincter muscle of *Zoanthus*, sp. ?, given by Hertwig (1882, pl. xiv., fig. 1), is evidently partly determined by this shrinkage.

ZOANTHUS, Lamarck, 1801.

Brachycnemic Zoantheæ, with a double mesoglœal sphincter muscle. The body-wall is unincrusted; the ectoderm is usually discontinuous; well-developed ectodermal canal system in the mesoglœa. Monœcious or diœcious. Polyps connected by a thin lamellar cœnenchyme, stolons, or, more rarely, free.

The synonymy of the genus Zoanthus is given by most recent writers upon the Zoanthidæ.

The following are the references to the genus Mammillifera, which, as shown below, must be merged in Zoanthus:

Mammillifera,	Lesueur, 1817, p. 178.
Mamillifera,	Blainville, 1834, p. 329.
Mammillifera,	Ehrenberg, 1834, p. 46.
Mamillifera,	Duchassaing, 1850, p. 11.
Palythoa (pars.)	Milne-Edwards, 1857, p. 301.
Zoanthus,	Gosse, 1860, p. 296.
Mamillifera,	Duchassaing and Michelotti, 1860, p. 327; 1866, p. 136.
Mammillifera,	Verrill, 1869, p. 495.
Mammilifera,	Hertwig, 1882, p. 111.
Polythoa and *Zoanthus* (pars.),	Andres, 1883, pp. 306 and 323.
Mammillifera,	Erdmann, 1885.
Mammilifera,	Hertwig, 1888, p. 35.
Mammillifera,	M^{c}Murrich, 1889, p. 117.
Mammillifera,	Haddon and Shackleton, 1891, p. 630.
Zoanthus,	M^{c}Murrich, 1896, p. 188.

The distinction between the Zoantheæ and other Actiniæ was first recognised by Cuvier in 1798, and the genus Zoantha first employed by Lamarck in 1801. Later, Cuvier (1817) restricted Zoanthus for Actinians occurring in groups adhering to a common base, which is sometimes broad and flat, and at other times a sort of creeping stem. In the same year, Lesueur (1817) separated, under the genus Mammillifera, those which have "A large cuticular expansion, serving as the base of numerous animals which, when contracted, assume the form of mammæ." This genus was received by Blainville (1834), Ehrenberg (1834), and Duchassaing (1850). Milne-Edwards (1857) united the included species under the genus Palythoa, established by Lamouroux (1816). Duchassaing and Michelotti (1860 and 1866) again separated the two genera, restricting Palythoa to the forms which have the integuments hardened by incrusting foreign matter. Gosse (1860) embraced, under Zoanthus, both the Palythoa of Lamouroux and the Mammillifera of Lesueur in addition to the other genera, all forms spreading "in either a linear or incrusting manner." Verrill (1869) distinguished the genus Mammillifera from Zoanthus "in having smaller, shorter, or more sessile polyps, and in the tendency to form continuous basal membranes, instead of linear stolons." Hertwig (1882) states that "Zoanthus and Epizoanthus are distinguished from Mammilifera and Palythoa by the fact that, in the former two, the polyps project plainly above the common basis, whilst in the latter two they are united up to the free end by basal cœnenchyma." Andres (1883) distributes the various species partly under Polythoa and partly under Zoanthus. Hertwig (1888), as a result of the researches of Erdmann (1885), separates Mammillifera from Zoanthus by the possession of only a simple mesodermal sphincter muscle. McMurrich (1889) follows Erdmann in this. Haddon and Shackleton, however, in their "Revision of the British Actiniæ" (1891), in a footnote to Mammillifera, state:—"The position of this genus cannot be settled until the type species have been recovered and sectionized"—the types being Lesueur's *Mammillifera auricula* and *M. nymphœa.* A form, covering considerable areas, occurs at Port Henderson and at Drunkenman Cay,* near Kingston, which I have no hesitation in identifying as closely allied to the *M. nymphœa*, of Lesueur, and with the better description of the species given by Duchassaing and Michelotti for colonies found by them at different islands of the West Indies. An anatomical study of this shows that, not only in the fundamental characters of the brachycnemic arrangement of the mesenteries and the double mesoglœal sphincter muscle, but also in many minuter details of structure, the species agrees with other members of the genus Zoanthus as described by Erdmann, McMurrich, and Haddon. Lesueur's description and figure of *M. auricula*, the other type species, leave no doubt that, when found and examined, it will also have the characters of a Zoanthus.

Since this was first written, Prof. McMurrich (1896) has obtained from the Bahamas an incrusting form which he identifies as *Mammillifera nymphœa*, and has shown that it is an undoubted Zoanthus. It is distinct from the Jamaican species (p. 345).

Following Haddon, McMurrich removes the species placed in his earlier paper under Mammillifera to Isaurus.

The use of the sphincter muscle, for specific purposes, is well exemplified in the genus Zoanthus. Differences are readily seen in the figures of the three following species, and these again can be distinguished from the sphincters of others represented elsewhere. A marked difference, in the muscle, exists in

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* The Port Royal Cays, known as Gun, Rackum, Drunkenman, Lime, Maiden, South, and South-east Cays, are a group of small coral islands outside Kingston Harbour. They are raised but a little above sea-level, some with and others without vegetation. The shores and shallow-waters around are the usual and most favourable spots for marine collectors.

the three Torres Straits species, described by Haddon and Shackleton (1891), compared with those of the West Indies. In all these latter, the proportion of the two parts differs much, the lower or proximal being several times larger than the upper or distal; in the former, very little distinction in size is met with. In *Z. Coppingeri*, the proximal (*i.e.* upper in figure, which would be lower or proximal in the extended condition of the polyp) is even slightly shorter than the distal; while in *Z. Jukesii* and *Z. Macgillivrayi*, the proximal is but slightly longer. Further, the muscle as a whole is much less developed than in the Antillean examples.

In partial contraction, a deep circular depression denotes externally the place of division between the two portions of the sphincter muscle. I use the term 'capitular fossa' for this, and speak of the two parts as the inner and outer capitula.

The genus Zoanthus, so far as I have observed it in the abundance occurring in Kingston Harbour and the Port Royal Cays, appears restricted in its distribution to a narrow belt of shallow water around the shores. It contrasts very markedly, not only in colour and firmness, but in its distribution with the equally abundant genus Palythoa. Colonies of the latter commence where the former begins to disappear, being most vigorous in the upper region of the breakers around the reefs. On the windward, more rocky side of the Cays, a distinct Zoanthus zone can be distinguished from the Palythoa zone; the former extends to a depth of one or two fathoms, and the latter to three or four fathoms, and gives place in its turn to the zone of living coral.

Zoanthus Solanderi, LESUEUR.

(Pl. XVII. A, fig. 1.)

Zoanthus Solandri, . . .	Lesueur, 1817, p. 177, pl. VIII., fig. 1.
Zoanthus dubia, ...	Lesueur, 1817, p. 177.
Zoanthus Solanderi, . . .	Milne-Edwards, 1857, p. 300, pl. c 2, fig. 3.
Zoanthus dubius, ...	Milne-Edwards, 1857, p. 300.
Zoanthus Solanderi, . . .	Duchassaing and Michelotti, 1860, p. 325, pl. VIII., fig. 1; 1866, p. 135.
Zoanthus dubius, ...	Duchassaing and Michelotti, 1860, p. 326, pl. VIII., fig. 2; 1866, p. 135.
Zoanthus (*Rhyzanthus*) *Solanderii*,	Andres, 1883, p. 327.
Zoanthus (*Rhyzanthus*) *dubius*, .	Andres, 1883, p. 329.

Form.—Polyps erect, cylindrical, smooth, thin-walled with lines of attachment of mesenteries showing through, connected with one another at the base by lamellar narrow cœnenchyme or free stolons, or may be solitary. Column usually non-pedunculate, practically of the same diameter throughout, but often with slightly expanded portions at the base. In extension the margin of the column is crenate, the elevations alternating with the outer row of tentacles; on partial retraction, the capitular fossa is well seen. Both inner and outer capitula bear fine ridges and grooves. In complete retraction, numerous minute capitular striæ can be seen only on the outer capitulum. Tentacles about 60, arranged in two cycles; one specimen had 32 in each row. Disc not much depressed, walls thin; the mesenterial lines can be seen through them; mouth slit-like, the œsophageal groove not distinguishable; œsophageal walls thin, showing the mesenterial lines; in some examples, the wall is thrown into ridges and furrows. Cœnenchyme little developed, appears only as a flattened expansion from one side of a polyp and connected with one or more other polyps near; in other cases, the connecting strand becomes constricted and stolon-like. Isolated polyps devoid of any cœnenchyme are met with, even when closely associated.

The polyps and cœnenchyme adhere firmly to the rocks or stones. New individuals arise by budding from the slightly expanded base of other polyps, and afterwards become more separated, the connecting tissue getting thinner and thinner until the polyps may become entirely isolated.

Colour.—Column in its lower part, especially when embedded in foreign matter, sand-coloured, becoming a dark blue or slate colour above. The margin has irregularly disposed, silvery white, triangular, narrow, radiating patches, often incomplete and variable in length; the toothed elevations are nearly opaque white. These white markings, which appear constant for the species, are best seen on partial contraction, at which time the inner capitulum appears as a distinct whitish, toothed, circular annulus. Colours of the tentacles and disc are variable. In a colony from Lime Cay both were a bright orange brown, and the peristome a bright green; in another large colony from Maiden Cay the tentacles were green on their inner aspect and dark brown on the outer, the disc a dark brown with bright green peristome; specimens at Rackum Cay showed a bright blue disc with green lips, and the tentacles a bright green.

Dimensions.—The height differs considerably, dependent upon the position of the polyps in a colony; it may vary from 2·7 cm. to 0·4 cm.; the diameter is about 0·6 cm., and is generally constant throughout the column, and independent of the length. The measurements are taken from specimens preserved in formalin, with but little contraction.

Locality.—Jamaica: Found in considerable abundance, growing on stones and coral rock, in shallow water, around the various Cays outside Kingston Harbour. The polyps are often partially embedded in sand and shore débris.

Range.—St. Thomas, Guadaloupe (Lesueur; Duchassaing and Michelotti).

Column-wall (Pl. XVIII. A, fig. 1).—A cuticle and sub-cuticla are present, the former having much adhering matter, such as diatoms; the sub-cuticla is in places minutely convoluted, evidently as a result of the excessive shrinkage of the mesoglœa. This is more especially seen in longitudinal sections.

The ectoderm of the column-wall is broad above, but very narrow below. It is much vacuolated, with only a small amount of cellular tissue remaining in the form of strands passing from the outer to the inner boundary; rarely a connecting strand of mesoglœa is seen. Some examples are not so highly vacuolated, particularly in the lower part. Abundant medium-sized, oval, non-staining nematocysts are present, the inner thread showing distinctly; pigment granules are met with at its internal boundary.

An irregular layer of spherical lacunæ appears in the mesoglœa, immediately below the ectoderm. Proximally the empty spaces extend further into the mesoglœa. The mesoglœa is broad in the region of the sphincter muscle, but narrows much below. Cells with long, fine processes are distributed sparingly throughout; delicate fibrils can also be easily seen passing from the ectoderm to an irregular, much broken, encircling sinus. The latter, situated either about the middle or very near the endodermal border of the mesoglœa, is formed of spaces varying in dimensions and form. They contain a small quantity of cellular tissue, and are connected with one another by larger or smaller canals, and also by canals with the ectoderm and the endoderm. The cells are multipolar in character.

The endoderm is low and contains abundant zooxanthellæ; nematocysts, similar to those in the ectoderm are present, and a weak circular muscle.

Sphincter muscle (Pl. XVIII. A, fig. 1).—The sphincter muscle is mesoglœal and double, the two halves being distinctly separated. The upper or distal is smaller, and located in large irregular cavities extending almost across the mesoglœa, diminishing both proximally and distally; the lining of muscle cells is thin. The lower or proximal part of the muscle is contained in a large number of small, scattered, mostly circular, mesoglœal cavities; the distal ones, however, are elongated, more like those in the upper. The muscle fibres are very small in section, and only a little loose tissue is present in addition.

Tentacles.—The ectoderm of the tentacles is without cuticle or sub-cuticla, and shows two kinds of nematocysts—an outer thick zone of the usual narrow form, and an occasional medium-sized, oval-shaped form similar to those in the ectoderm of the column-wall. The mesoglœa is very thin.

The endoderm is well developed, and crowded with zooxanthellæ. Both the ectodermal and endodermal musculatures are weak.

Disc.—The ectoderm of the disc is almost devoid of nematocysts. The mesoglœa is a little thicker, and the endodorm much thinner than in the tentacles. The endodermal muscle is seen in longitudinal sections.

Œsophagus.—The nematocyst and nuclear zone in the ectoderm is very regular, and situated close to the outer surface, while a non-staining nervous tissue intervenes between it and the mesoglœa. The latter is very thin, and the endoderm resembles that of the mesenteries. In transverse sections, the œsophagus is oval. In the upper region, the ectoderm is not thrown into folds, and the œsophageal groove is barely apparent. Lower, as many as twelve longitudinal folds may be present on each side, and a slight indication of a groove. The mesenteries are attached to the œsophagus at about equal distances all the way round. The ectoderm is reflected on the mesenteries, and continued downwards as the mesenterial filaments.

Mesenteries.—The mesenteries are of the brachycnemic type; generally about thirty pairs are present; one specimen had fifteen perfect mesenteries on one side, and only thirteen on the other.

The endoderm contains abundant zooxanthellæ, and medium-sized oval nematocysts. The digestive endoderm (1889, p. 116; 1891, p. 622) is not very thick.

The basal canal is large in both the perfect and imperfect mesenteries. It is elongated in the former, and full of deeply-staining cells.

The parieto-basilar muscles are clearly distinguishable, as also the retractor muscle of the mesenteries. The mesoglœa is folded to support the muscle.

Gonads.—No reproductive elements were present in any of the examples studied.

The following may be regarded as distinguishing anatomical characters:

(*a*). Pigment limited to the inner portion of ectoderm;
(*b*). Mesoglœal lacunæ;
(*c*). Form of sphincter muscle.

The Jamaican form above described appears to unite the two species *Z. Solandri* and *Z. dubia*, as originally described by Lesueur, and as known to Duchassaing and Michelotti from the same localities. Considering the variation in colour noted, it is evident that little importance can be attached to it. Referring to the first species, Duchassaing and Michelotti state: "Le couleur de cette espèce est sujet à varier, mais nous n'y avons jamais remarqué à l'état vivant la teinte qui lui donne M. Milne-Edwards dans l'atlas qui accompagne son oûvrage sur les coralliaires, la teinte verte se montre toujours dans une parti ou sur la totalité du corps de ces animaux." Some account must be taken of the character given by Lesueur that, when the animal is contracted, the summit is marked with deep blue angular spots and white lines, a feature agreeing with the present specimens. The polyps are usually non-pedunculate, resembling the figure of *Z. dubius* given by Duchassaing and Michelotti; but pedunculate forms, agreeing with Lesueur's original figure, also occur.

Zoanthus flos-marinus, DUCHASSAING and MICHELOTTI.

(Pl. XVII. A, fig. 2.)

Zoanthus flos-marinus, . . .	Duchassaing and Michelotti, 1860, p. 326, pl. viii., fig. 6.
Zoanthus flos-marinus, . . .	Andres, 1883, p. 328.
Zoanthus flos-marinus, . . .	McMurrich, 1889, p. 113, pl. vii., figs. 3, 4.

Form.—Polyps erect, smooth, thin-walled, pellucid, clavate or cylindrical; arising either directly from a thin band-like incrusting cœnenchyme, or from a free irregular stolon, or from the base of one another. In full retraction, a little swollen above; in partial contraction, inner capitulum very narrow, with 24 to 30 minute rounded denticulations or capitular ridges, continued as thin lines for some distance down the column, and corresponding in number and alternating with the outer row of tentacles.

Tentacles dicyclic, slightly entacmæous, smooth, acuminate, overhanging in full extension, variable in number, from 48 to 60. In one colony, the numbers counted were 60, 52, 58, 54, 50, 54, 58; in another colony, 56, 50, 50, 48. In this latter colony, a curious condition of the tentacles was met with, each bearing near its origin one or two small tubercles,* suggestive of an additional cycle.

Disc thin-walled, with the radiating mesenterial lines showing through; outer part grooved, overhanging in full extension; central portion elevated and rounded; mouth slit-like. Cœnenchyme occasionally band-like and incrusting, more often stolon-like, constituting an irregular connexion for the polyps. Polyps, all about the same size, are often closely associated in a colony, and incrust some rock or stone; at other times, they are loosely attached to any object, and form bunches connected with one another in an irregular fashion by the loose stolon-like cœnenchyme. Sometimes the polyps are united to one another some distance above the base. Examples on the upper surface of stones are usually short and cylindrical; but those along the sides and underneath, or in crevices, become much elongated and narrow below.

Colour.—Lower part of column sand-coloured; upper dark green or lead colour; tentacles yellowish-green, blue-green, or brown; disc various light and dark shades of blue and green, often mixed with yellow and black; peristome a bright yellow or green; a darker triangular area at each or only one angle of the mouth may be present.

Dimensions.—Dimensions variable; column usually about 1·7 cm. in length;

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* Verrill records a similar condition for *Mammillifera Danæ* (1869, p. 496), and for *Epizoanthus elongatus* (p. 498). It is not general in the present species.

diameter of capitulum in living retracted state 0·5 cm.; diameter of disc in extension 0·5 to 0·8 cm.; inner tentacles 0·25 cm. long.

Locality.—Jamaica: The commonest Zoanthus found around all the Cays. It occurs in masses, covering large surfaces of the rocks and stones in shallow water. Very often the polyps are almost embedded in débris of sand, mud, and calcareous algæ, so that in extension only the closely associated discs are exposed.

Range.—Bermudas (M^c^Murrich); St. Thomas (Duchassaing and Michelotti).

Column-wall.—The cuticle, sub-cuticla, and ectoderm are of the same character as in the previous species. In preserved specimens the cuticle readily separates. Abundant oval nematocysts are present in the ectoderm, especially in the distal part. The boundary between the ectoderm and mesoglœa is not well defined, cells and cell processes from the former passing into the latter.

The mesoglœa is broad in the region of the lower sphincter muscle, but becomes thinner in both directions. It is without the empty lacunæ below the ectoderm, which are such a marked feature in the former; large and small spaces occur, the former containing but little cellular tissue and an occasional nematocyst. In transverse sections a broken encircling canal is shown, in some sections communicating with the ectoderm. Most of the cell-islets throughout the mesoglœa contain fine pigment granules. The endoderm is occasionally elevated between the mesenteries, and triangular in transverse sections; elsewhere it is very thin, and loaded with zooxanthellæ. The endodermal muscle is clearly distinguishable.

Sphincter muscle (Pl. XVIII. A, fig. 2).—The form and arrangement of the cavities of the sphincter muscle are best realized from the figure. It bears a resemblance to the previous one, but the smaller proximal cavities are much more uniformly and regularly distributed. The smaller cavities terminating the proximal half are more numerous in some examples than in the one figured. In addition to the lining muscle cells, rounded cells occur in the cavities.

Tentacles.—The ectoderm is devoid of the cuticle and sub-cuticla. It is made up of narrow columnar cells, with oval, deeply-staining nuclei, amongst which are small oval nematocysts; pigment granules and a weak ectodermal muscle occur, the latter on very numerous, fine, mesoglœal plaitings. The mesoglœa is thin and a little plaited on the endodermal border for the support of the circular muscle.

The endoderm is very thick, leaving only a small lumen; it is crowded with zooxanthellæ.

Disc.—The disc is much like the tentacles in structure, but the endoderm has about the same thickness as the ectoderm.

Œsophagus.—In section, the ectoderm of the œsophagus shows three strongly marked zones, all of nearly equal breadth; an outer non-staining ciliated portion; a middle deeply-staining zone with oval-shaped nuclei, granular gland cells and narrow nematocysts; and an inner, slightly narrower, nervous layer, containing a few circular nuclei, and a little pigment matter. The mesoglœa and endoderm are each narrow. In transverse section, the œsophageal groove is not very pronounced, and the ectoderm is thrown into folds in some cases, in others not.

Mesenteries.—The mesenteries are brachycnemic in arrangement and very thin. In one specimen, twenty-four pairs were present; in another, twenty-one. The endoderm is well developed, made up almost entirely of zooxanthellæ and medium-sized, oval-shaped nematocysts. The mesoglœa is folded and plaited on one side for the support of the longitudinal retractor muscle. A basal canal is developed in some a little distance from the column-wall, but is not present in others.

The reflected ectoderm, mesenterial filaments, and endoderm swollen in the lower region, are similar to those figured and described by M^c^Murrich (1889, p. 115, pl. vii., figs. 3, 4), and the endoderm has embedded in it what I take to be the delicate acicular siliceous spicules referred to by him. The digestive endoderm is not so thickly developed in the previous species. The Drüsenwulst of von Heider (1895, p. 129) can be well studied.

Gonads.—None of the numerous specimens examined were fertile.

I identify this very common Jamaican form as the *Zoanthus flos-marinus* of Duchassaing and Michelotti, rather from the description by Prof. M^c^Murrich of specimens from the Bermudas (1889). The diagnosis of the original authors is very incomplete for this variable genus. They state the tentacles to be thirty-six, while the later writer gives them as fifty to sixty in number, a number agreeing with the Jamaican examples. Andres places it amongst his *Zoanthi dubii.*

It may readily be distinguished from *Z. Solanderi* by its smaller size, usually clavate form, and stolon-like cœnenchyme; and from *Z. pulchellus* by never forming a broad lamellar cœnenchyme.

Zoanthus pulchellus (Duchassaing and Michelotti).

(Pl. XVII. a, fig. 3.)

Mamillifera pulchella, Duchassaing and Michelotti, 1866, p. 137, pl. vi., fig. 4.
Polythoa (*Mammothoa*) *nymphosa*, Andres, 1883, p. 320.

Form.—Polyps erect, cylindrical, short or elongated, smooth, usually closely grouped, rising from a thin, tough, lamellar, incrusting cœnenchyme. In retraction, either a little enlarged above or of the same diameter throughout, terminating in a rounded or slightly conical manner, and showing a central aperture and numerous fine radiating capitular ridges; where the polyps are more separated, they often appear as low mammiform prominences. In partial retraction, a double capitulum is formed by the groove situated between the two parts of the sphincter muscle. In full expansion, the disc and capitulum are greatly extended, so that, when all the polyps in a colony are in this state, their margins are wholly in contact. The mutual pressure produces a polygonal outline, giving rise to the appearance of a mosaic work of green discs with elevated, often pink, centres, the two rows of dark short tentacles simulating a thick cementing material. Tentacles short, digitiform, overhanging in extension, arranged in two alternating rows of about thirty in each. The number may be slightly more or less. Disc depressed below the thickened margin; the mesenterial lines are seen through the wall; in expansion the oral cone is considerably elevated, and the mouth slit-like; the œsophageal groove is not obvious. The cœnenchyme is smooth, continuous, lamellar, adhering firmly to the rocks and stones, and following the larger irregularities of the surfaces. The polyps all arise independently, generally in close association, but may be further separated, when the cœnenchyme becomes more ribbon-shaped. Owing to the thinness of the body-wall, there is often a partial collapse and transverse wrinkling in alcoholic specimens, especially in the more elongated examples.

Colour.—Column in lower part of elongated forms is pale buff and transparent, with the white mesenterial lines showing through; upper part olive blue; capitulum lighter with green radiating lines, seen more especially on retraction. Tentacles, nearly always dark brown, may be green or olive. Disc generally a bright green, with light radiating lines corresponding with the internal mesenteries; sometimes a pale green or yellow. In many, a darker triangular area extends towards the margin from each of the two extremities of the mouth; one is often more pronounced than the other. Œsophagus green, with white lines showing through. Peristome in many colonies pink, in others a bright green; more rarely yellow. An olive brown colour is first extracted by alcohol, leaving the colonies uniformly dark green, probably due to the abundant internal zooxanthellæ; later the polyps become a buff colour, a little darker above, and the mesenterial lines show through.

Dimensions.—Average diameter of column, 0·6 cm.; diameter of capitulum, in full expansion, 0·8 to 1 cm.; length of column very variable, depending largely upon the position of the polyp in the colony, average length 1·3 cm.; some may attain a length of nearly 3 cm., while others extend only 0·4 cm. above the cœnenchyme. Tentacles 0·2 to 0·3 cm. in length. Colonies often 20 or 30 cm. across. When preserved in alcohol, considerable contraction of the polyps occurs.

Locality.—Jamaica: Found in great abundance, forming large incrusting colonies on the rocks and stones in the shallow waters near the rocky parts of the shore at Port Henderson, Kingston Harbour, and on the coral-rock at Drunkenman and other Cays.

Range.—St. Thomas (Duchassaing and Michelotti).

Column-wall (Pl. XVIII. A, fig. 3).—The column is partially coated with a layer of foreign matter, mostly diatom frustules and fine mud. The ectoderm is very thin, nearly continuous, and only slightly vacuolated. A sub-cuticla occurs, as in most species of the genus, more noticeable on the lower part; transverse strands of mesoglœa are rarely seen. The mesoglœa is very variable in thickness, according to the state of extension or contraction of the polyp; it is best developed in the region of the sphincter muscle, and also as the cœnenchyme is approached; isolated cells, with elongated processes, occur; fine processes are seen extending across the mesoglœa from the ectoderm to the endoderm. Some of the more peripheral cell-islets contain dark granular pigment matter. An irregular, partially encircling, canal system is present, situated in the upper part nearer the endoderm, among the cells of which are nematocysts. The canals, in some sections, are seen definitely connected with the ectoderm.* The mesoglœa is much shrunk in preserved specimens, producing, especially in longitudinal sections, a very irregular external outline, followed by the ectoderm and foreign material. The endoderm is very narrow, crowded with zooxanthellæ and small oval nematocysts, and gives rise to a weak endodermal muscle.

At the base, the ectoderm is thinner; the sub-cuticla is more clearly seen, also the ectodermal canals in the mesoglœa communicating with the ectoderm. Numerous irregularly distributed cœlenteric canals, lined with ciliated epithelium, pass along the base of the polyps through the cœnenchyme, and connect the cavity of one polyp with that of another. The cells of the canals are somewhat glandular, and a thin lining musculature is present.

Sphincter muscle (Pl. XVIII. A, fig. 3).—The upper (distal) portion of the sphincter muscle is much smaller than the lower (proximal). It is contained in about twenty small mesoglœal cavities, arranged in an irregular row. The first section of the larger muscle is contained in an irregular series of small cavities stretching for some distance across the mesoglœa. The cavities are largest about the middle; lower they are again smaller, and located for the most part nearer the ectoderm. The lining of muscle cells is very thin, a few nucleated rounded cells are also present. In the figure of the muscle cavities, the latter are represented as flattened and almost closed. This condition is evidently due to the method of preservation in alcohol. Specimens preserved later, in formalin, have

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* Hertwig (1882, p. 112) found a similar connexion in *Zoanthus Danæ* (?). McMurrich states that, in *Z. sociatus*, he has observed the basal canal in the mesentery communicating with one of these spaces, and considers it open to question whether the cells in the large cavities of the mesoglœa are not in reality endodermal in their origin.

the cavities larger and more circular, as in the figures of the two previous species. The sphincter in this species differs from that of the two former in that the proximal part commences above with numerous small cavities.

Tentacles.—The ectoderm of the tentacles is ciliated and without any cuticle or sub-cuticla; it is much thicker than that of the column, and small nematocysts occur in restricted areas. The weak ectodermal muscle is supported on minute plaitings of the mesoglœa. The mesoglœa is thin, with a few isolated cells. The endoderm is thicker than the ectoderm, leaving scarcely any lumen in retraction. Abundant zooxanthellæ, small oval nematocysts, and a weak endodermal muscle are met with.

Disc.—The ectoderm of the disc is nearly as thick as that of the tentacles; the nuclei stain very deeply; an ectodermal musculature occurs. The mesoglœa is broad, destitute of cell-enclosures, and contains a few isolated cells. The endoderm is like that of the mesenteries, and has an endodermal musculature.

Œsophagus.—The ectoderm in the œsophagus is rather broad and ciliated, and thrown into about eight deep longitudinal folds on each side, partially followed by the mesoglœa; the œsophageal groove is elongated, occupying in some sections about one-third the transverse area of the œsophagus. The appearance is much the same as that figured by McMurrich for the stomadœum of *Z. sociatus.* The ectoderm contains an occasional small oval nematocyst, in addition to the usual abundant narrow ones, and also a little pigment matter on its inner border. The mesoglœa is thinner than the ectoderm, and contains no cell enclosures.

Mesenteries (Pl. XVIII. A, fig. 4).—The number of mesenteries varies, twenty-eight perfect ones occurring in one specimen, and twenty-six in another, corresponding with the varying number of tentacles. A slight parieto-basilar muscle is found on each side. The endoderm has zooxanthellæ and small nematocysts. A few isolated cells occur in the mesoglœa. Below the œsophagus, the mesenteries, with the mesenterial filaments, assume, in transverse section, first a sagittate appearance, and lower a clavate form; in the lower region of the œsophagus, the reflected ectoderm has the characteristic pinnate appearance, the whole corresponding with that described and figured by Haddon and Shackleton for *Z. Macgillivrayi* (1891, p. 681). Nematocysts occur.

A very weak musculature extends along the whole surface of both sides of the mesentery, the mesoglœa being slightly plaited in places. A single basal canal passes the whole vertical length; in the perfect mesenteries, it is oval in section in the distal region, but becomes elongated and stretches nearly the whole width in the basal part of the polyp.

In the imperfect mesenteries, the basal canal remains approximately circular in section. The tissue inside the canals is of the same character as the endoderm, being crowded with zooxanthellæ and nematocysts.

Gonads (Pl. XVIII. A, fig. 4).—Ova and spermaria are borne in close proximity on the perfect mesenteries, both above and below the œsophagus. They were met with in three specimens taken from the same colony, but none were present in several examples sectionized from another colony.

Cœnenchyme.—The cœnenchyme is of similar structure to the body-wall, but the mesoglœa is much thicker and broken up by large ciliated cœlenteric canals passing in all directions; the endodermal lining is loaded with zooxanthellæ, and has a weak musculature. Isolated cells with fine processes, and the smaller ectodermal canals occur.

For some time during the preparation of this Paper, I had regarded this species, with little or no hesitation, as the *Mammillifera nymphæa* of Lesueur (1817). In the meantime, Prof. M^c^Murrich identified, with some amount of uncertainty, a form from the Bahamas as Lesueur's species. The external characters of the Jamaican representative agree with those of the Bahaman, as far as the latter are given, but a comparison of the sphincter muscles shows that they are undoubtedly distinct. Prof. M^c^Murrich, from an examination of my material and slides, entirely agrees with this. Whether his identification of the Bahaman form with that which Lesueur described be correct or not, it seems best that his conclusion should be followed for the future, seeing that with the addition of the anatomical features, the characters of the species are definitely fixed once for all. There must nearly always be an amount of uncertainty in identifying the species of the older authors, where external characters only were taken into account. I have therefore changed my manuscript identification of this species to that of *Mammillifera pulchella* of Duchassaing and Michelotti (1866), a form these authors regarded as a doubtful variety of *M. nymphæa.*

Isaurus, GRAY, 1828.

Large brachycnemic Zoantheæ, with a single mesoglœal sphincter muscle. The body-wall is unincrusted; the ectoderm discontinuous; ectodermal and endodermal bays and small canals in the mesoglœa. Monœcious or diœcious. Polyps in small clusters or solitary.

Prof. Haddon and Miss Shackleton give (1891, pp. 682–4) a full discussion of the genus defined by them as above. They dwell particularly upon the reason why it should not be merged into the genus *Mammillifera* of Lesueur, as, accepting the characters Erdmann gives (1888, p. 35), has been done by M^c^Murrich (1889, p. 117). In his more recent paper (1896, p. 191), the latter author adopts *Isaurus.*

Isaurus Duchassaingi (Andres).

(Pl. XVII. A, fig. 4.)

Zoanthus tuberculatus, . . .	Duchassaing, 1850, p. 11.
Zoanthus tuberculatus, . . .	Duchassaing and Michelotti, 1860, p. 327, pl. viii., fig. 5.
Antinedia tuberculata, . . .	Duchassaing and Michelotti, 1866, p. 136, pl. vi., figs. 2, 3.
Antinedia Duchassaingi, . . .	Andres, 1883, p. 330.
Isaurus Duchassaingi, . . .	M^{c}Murrich, 1896, p. 190, pl. xvii., figs. 6–8.

Form.—Base firmly adherent, expanding somewhat over the incrusted surface; usually much larger than the diameter of the column; irregular in outline. The flattened expansion may be regarded as a slightly developed cœnenchyme; but, although closely associated, the polyps were rarely connected with one another.

Column variable in shape, may be cylindrical or clavate, generally more expanded towards the base; slightly overhanging so as to present a concave and a convex aspect; the capitulum appears as a disc in retracted specimens, and is placed obliquely so that the small central aperture indicating the mouth is below the upper termination of the column. Proximal part, for from one-third to one-half of the total length of the column, smooth, with thin partial annuli showing through, which may become depressions on shrinkage; in the later state, numerous well-marked longitudinal ridges and furrows may also be rendered obvious. The column on its sides and convex aspect bears irregular rows of rather large, rounded tubercles, distinct from one another; the concave, shorter portion is smooth, giving rise to a marked asymmetry; four principal rows, of from five to eight tubercles, alternate with other rows of two or three smaller protuberances. Around the margin of the terminal disc is an incomplete circle of eight or nine tubercles, separated by deep depressions. These correspond with the rows and extend nearly round the margin, diminishing in size towards each extremity of the partial circle.

The flattened or slightly elevated and dome-shaped capitular disc is partially enclosed by these, and bears radiating ridges and furrows, not all equally developed; eight or nine which alternate with the marginal protuberances are more prominent than the one or two groups alternating with them. A depression indicates the position of the mouth. One young specimen, 2·5 cm. long, is quite smooth, having no elevations. In the living condition, the column-wall is firm, very tough, and partially transparent, so that the presence of the internal organs can be distinguished.

In none of the specimens could the disc and tentacles be noted externally; the individuals, as appears to be usually the case, maintaining a retracted condition.

Colour.—Cœnenchymatous base colourless in some, irregularly greenish brown in others; column dark brown, mottled with green and black, the pigment appearing in granular form. The green colouring matter seems largely external, and due to adhering unicellular algæ.

Dimensions.—Diameter of base may be 1·7 cm.; diameter at commencement of column varies from 0·4 cm. to 1 cm.; average diameter of column 0·6 cm.; height, from 2·2 cm. to 4·2 cm.; tentacles, measured in sections, 0·3 cm. long.

Locality.—Seven specimens were found associated and firmly adhering to a small block of coral-rock on the south-east side of Drunkenman Cay.

Column-wall.—The cuticle on the outside is devoid of adhering foreign matter, except in places where a unicellular green alga is attached, giving rise to the greenish patches seen on the living animal. The sub-cuticla is of regular thickness, but enlarged a little where it communicates with the internal mesoglœa by strands across the ectoderm. The ectoderm is thick; the nuclei of the individual cells show no regular zonal arrangement; it is broken up by the strands of mesoglœa into somewhat cubical or spheroidal blocks; large, thick-walled, highly refractive zooxanthellæ, and occasional large colourless stinging cells are present in places. In the uppermost part of the column the sub-cuticla is absent, and the ectoderm continuous. The internal boundary is often not clearly defined, portions being, as it were, cut off and isolated, and, as still smaller parts, often only individual cells, sunk further into the mesoglœa.

The mesoglœa is very thick, and contains abundant cell-inclosures, and uniformly distributed small cells with granular protoplasm. In the lower parts more especially these take the form of small communicating canals. M^c^Murrich refers to the alteration in histological structure which some of the cells undergo in the mesoglœa, by which they become filled with refractive, deeply staining granules, and suggests (p. 118) that they may be concerned in the formation of the mesoglœa, their granules being particles which will later on be added to the matrix of the mesoglœa. Many of the cells in my sections, generally in limited areas, appear to go a stage beyond, and instead of the granules filling the cells, they become arranged peripherally, giving the appearance of a thickened granular cell-wall, a distinct central nucleus remaining (fig. 6, Pl. XVIII. A).

The endoderm is thin, and contains abundant zooxanthellæ and small stinging cells. A circular endodermal muscle occurs along the greater part of the length of the column. Endodermal bays are met with at different levels, extending nearly as far as the ectoderm, and evidently correspond with the thin annuli noticed amongst the external characters. The endodermal muscle follows the outgrowths for only a short distance. Perhaps the bays serve to give flexibility to the column. The projections seen on the upper part of the column are shown to be due to thickenings of the mesoglœa, and contain a cavity lined with cells continuous with the endoderm, as is recorded by McMurrich (p. 192), for the Bahaman forms; further, some polyps do not show any of the ectodermal bays mentioned by McMurrich, and by Haddon and Shackleton, while they occur in others.

Sphincter muscle (Pl. XVIII. A, fig. 5).—The single mesoglœal sphincter muscle is strong, elongated, and in longitudinal sections extends nearly across the mesoglœa. Proximally, the mesoglœal cavities are small and circular; distally, they are oval and more elongated; the muscle cells are arranged in different directions, and constitute a very thin layer, the remainder of the cavity being partially occupied with loose rounded cells, or more usually appears as an empty space. For the greater part of its length, the muscle cavities give a vesicular character to the mesoglœa. The appearance is figured by McMurrich, but the cavities appear more numerous and not so elongated in the Jamaican form. Some of my preparations show the constriction he refers to, but I have not obtained the long, branching, terminal cavities.

Tentacles.—The tentacles, seen in longitudinal sections, are as long as usual in the Zoanthidæ, and are acuminate in form. The ectoderm is very thick and shows a peripheral zone of colourless, narrow nematocysts and gland cells; below this a zone of deeply staining small nuclei; nearer the mesoglœa abundant pigment granules occur, along with a few scattered nuclei. The mesoglœa is thin, but thrown into fine, long, branching plaits on the ectodermal side for the support of the muscle, to such an extent that, in some sections, the mesoglœa appears as if it had enclosed parts of the ectoderm. This condition is also described for *I. asymmetricus* (1891, p. 685). The endoderm, even in the state of retraction, is much thinner than the ectoderm, an unusual condition in the Zoanthidæ. It contains numerous ordinary zooxanthellæ, and occasionally others with thick, highly refractive walls, such as are found in the ectoderm of the body-wall, and are there also associated with the thin-walled form.

Disk.—The disk much resembles the tentacles, but the ectoderm is not so thick, nor nematocysts so abundant. The nuclei are more uniformly distributed; but the peculiar ectodermal musculature is similar in places. An endodermal muscle also occurs.

Œsophagus.—The œsophagus is considerably folded; the three layers maintain a somewhat uniform thickness, but the mesoglœa follows in places the more deeply folding ectoderm. It is slightly truncated opposite the sulcar directives, the two mesenteries extending from each corner being the only indication of an œsophageal groove. The ectoderm is ciliated; the small, deeply-staining oval nuclei are arranged in a band a little below the surface. Gland cells, and elongated nematocysts, showing a spiral thread, occur sparingly. The mesoglœa is thin, and small granular cell-enclosures are scattered throughout.

The endoderm is a low band of cells resembling that of the mesenteries; zooxanthellæ, small nematocysts, and a weak muscle are present.

Mesenteries.—The mesenteries are brachycnemic in type, and the perfect ones are arranged at about equal distances apart all round the œsophagus. Twenty-one pairs are present in one specimen. The endoderm is thin and crowded with zooxanthellæ and small oval nematocysts. A parieto-basilar muscle and a vertically arranged musculature occur on each side. The mesoglœa is well developed throughout. Towards the insertion of the mesentery into the body-wall it is thrown into small irregular plaits or pennons; still nearer it narrows a little. A basal canal and numerous irregular vertical canals and cell-enclosures occur the whole length of the mesenteries, continuous in places with those in the mesoglœa of the column-wall. The reflected ectoderm rarely occurs, but the mesenterial filaments are met with as usual. Towards the base of the polyp the mesenteries begin to unite with one another, and ultimately form a reticulum-like structure filling the whole of the cœlenteron.

Gonads.—No gonads were present in three examples sectionized.

From the latest researches of Professor McMurrich, it appears that the West Indies possess two species of Isaurus, one from Bermuda, identified by him as the *Isaurus tuberculatus*, of Gray (1828), and another, the *Zoanthus tuberculatus*, of Duchassaing (1850), obtained from the Bahamas in the Northrop Collection, and previously collected from Guadaloupe and St. Thomas. In his Bermudan paper (1889 *a*), McMurrich, however, considered Gray's form as identical, not only with the Bermudan examples, but also with the *Z. tuberculatus*. Owing to these later results, and the specific name *tuberculatus* being occupied by both forms, he has followed Andres and adopted the term *Duchassaingi* for the Bahaman examples and for those known to Duchassaing and Michelotti.

Professor Haddon and Miss Shackleton (1891) have described as new, a form, *I. asymmmetricus*, obtained by the senior author from Torres Straits. In doing this they state (p. 684):—"It is undoubtedly nearly allied to the *Mammillifera tuberculatus* of McMurrich. The specific differences are the lesser number and greater size of the tubercles, though their diameter is about the same, and their asymmetrical arrangement; the height of our species is about double that of the West Indian form."

The specimens described above seem to me to unite in a very marked manner the two West Indian and also the Torres Straits examples. I regard the differences in the external appearance of the tubercles, transverse annulations, &c., as largely dependent upon age and method of preservation. Even in the details of microscopic structure, the Jamaican specimens appear to agree very closely, particularly so in the peculiar mesoglœal plaitings of the tentacles and the form of the mesenteries.

Colonies obtained later from Port Antonio convince me that it will be found impossible to maintain the separation of the three species, to such an extent is the form variable in external characters and structure.

Gemmaria, DUCHASSAING and MICHELOTTI, 1860.

Brachycnemic Zoantheæ, with a single mesoglœal sphincter muscle. Solitary, or connected by cœnosarc. The body-wall is incrusted. The ectoderm is usually discontinuous, but may be continuous. Lacunæ and cell-islets are found in the mesoglœa. Diœcious or monœcious.

The only difference between the definition of the genus here given and that in a former publication (1896, p. 142) is in connexion with the gonads. All the species hitherto examined have had the male and female reproductive cells, where present, in different individuals; but in the first representative described below, both ova and spermaria occur on the same mesenteries (Pl. XVIII. A, fig. 8). It has already been shown (1891, p. 623) that a similar monœcious and diœcious condition exists in the genus Zoanthus, and doubtfully in Isaurus.

Gemmaria variabilis, n. sp.

(Pl. XVII. A, fig. 5.)

Form.—Polyps erect, firm, smooth, arising independently from a lamellar cœnenchyme, or from around the base of one another, or may be solitary; often cylindrical in retraction; slightly enlarged and flattened distally, or occasionally narrowing and terminating bluntly; others, mostly long examples, are clavate, being narrow below and expanding above either slowly or more suddenly; transversely wrinkled, especially in spirit specimens. Capitulum with about thirty ridges and furrows. Tentacles acuminate, arranged in two alternating rows of about thirty in each row; the number may vary considerably, forty in each row being counted in one example. Peristome considerably raised; the mouth elongated and slit-like.

In full expansion, the capitulum and disc are much enlarged in proportion to the diameter of the column; and the individuals in a colony are so closely aggregated that, reaching the same level, the margins come in contact, and by mutual pressure produce a polygonal outline, leaving no interstices. Where examples in a colony incrust an irregular surface, or are fixed to the underside of stones, the columns elongate sufficiently to bring all the individuals, with the disc looking upwards, to about the same level. A living colony when fully expanded thus presents the appearance of a mosaic work of brown or green depressed discs, with margins of a dark-brown colour.

When alive, polpys are found under three conditions:—

(1) Retraction, where the disc and tentacles are entirely withdrawn, leaving only a very small central opening.

(2) Partial expansion, with a small portion of the disc visible. This is considerably depressed, and the tips of the tentacles protrude from between the thick capitulum and the disc.

(3) Full expansion, in which the disc is completely exposed and only slightly below the capitular margin, and the tentacles are quite free. In this state the capitula are in contact with one another.

Cœnenchyme present around the base of each polyp, but otherwise not very freely developed, appearing rather as a consequence of the origin of the polyps from one another by basal gemmation, and connecting them only as a flattened band or ribbon; the band may become constricted, and finally the individuals sever their connexion with one another.

Colour.—Lower part of column light buff, upper dark brown. Tentacles usually dark brown, but may be olive or green. Disc in some is dark brown, with green radiating lines, and the peristome a bright green; or the disk may be green and the peristome brown; in others the disc and peristome are both bright green. Œsophagus colourless. The ectoderm containing the brown pigment readily rubs off when handled, the colourless mesoglœa, with the enclosed sand grains, being exposed. In alcohol, the brown colour is first extracted, leaving the colony a uniformly dark green; later this gives place to a dirty buff colour.

Dimensions.—The dimensions of the individual polyps vary considerably even in the same colony, being largely dependent upon the position of the polyp in the colony. In the large masses spreading over an even surface, the individuals are all of the same thick-set type and approximately of uniform size. When the colonies are smaller, and the incrusted surface irregular, the specimens in the depressions become elongated in order to attain the same level as the majority. The length of the column of one of the longest is 5 cm., the diameter 1·2 cm.; an average height is 1·5 cm., and diameter 0·7 cm.; diameter of expanded disk 2·3 cm.; tentacles about 0·3 cm. in length. Owing to the rigidity of the column-wall there is not much contraction in preserved specimens.

Locality.—Found growing very abundantly upon rocks and stones in shallow water at Port Henderson, Kingston Harbour. Numerous irregular colonies are to be met with, sometimes one or two feet across; one was over two yards in length, and one to two feet broad. Incrusting sponges grow freely on the cœnenchyme and amongst the polyps, and Ophiuroids meander around.

The specific name has reference to the amount of variation met with in the various external features of the polyps.

Column-wall (Pl. xviii. a, fig. 7).—The cuticle of the column-wall is thickly coated below with a layer of foreign matter, principally diatoms. The ectoderm is continuous, and presents irregular internal limitations, especially towards the upper part of the column. This is due partly to the presence of incrustations, but also to the ectoderm passing insensibly into the cell-enclosures of the mesoglœa. Numerous zooxanthellæ occur, and occasionally large colourless oval nematocysts, showing the coiled internal thread. The incrustations are sand grains, sponge spicules, and tests of Radiolarians, and extend from the inner border of the ectoderm to beyond the middle of the mesoglœa.

The mesoglœa is thicker above and below than in the middle; numerous cells occur bearing elongated processes, and cell-enclosures of various dimensions uniformly distributed. Fine radiating processes extend from the endodermal boundary, apparently throughout the layer; the large cell-islets contain zooxanthellæ and large oval nematocyts, as in the ectoderm.

The endoderm is of medium height, and contains zooxanthellæ and pigment granules; the circular endodermal muscle is easily distinguished.

Sphincter muscle (Pl. xviii. a, fig. 7).—The sphincter muscle is single and enclosed in an extended series of small mesoglœal cavities, varying but slightly in size, shape, and distance apart. It is situated nearer the endoderm. The cavities in the upper part are a little larger, and the lining muscle-fibres are arranged in various directions, many being cut obliquely. A few small spherical cells are also present in the middle of the cavities.

Tentacles.—The ectoderm is thick and has an outer layer of small narrow stinging cells, and below this abundant deeply staining oval nuclei and numerous glandular cells. The mesoglœa is broad, and contains isolated cells and foreign incrusting matter. An ectodermal and an endodermal musculature occur.

Disc.—The ectoderm is very broad and contains zooxanthellæ and glandular cells. The mesoglœa is nearly as thick as that of the column-wall, but contains no foreign inclosures; minute cellular strands and a few cell-islets with large oval nematocysts occur in it. In the peripheral part of the disc, the mesoglœa is very thin, while the ectoderm is a little thicker than in the more central region. The endoderm is low and contains zooxanthellæ; a weak endodermal muscle on plaitings of the mesoglœa occurs.

Œsophagus.—The œsophagus is oval-shaped in transverse sections, with a well marked truncated œsophageal groove, the sulcar directives extending from the corners. The ectoderm is thrown into longitudinal folds, not followed by the mesoglœa; twelve occur on each side in one specimen, but there may be as many as 15 or 18. The large colourless nematocysts and pigment granules are present, and a weak nerve layer.

The cells are longer at the groove. The mesoglœa is thin, but thickens towards the same place, and contains cells. The endoderm is low, and shows an outer zone of nuclei and an inner non-staining zone; the endodermal muscle is supported on mesoglœal plaitings.

Mesenteries (Pl. XVIII. A, fig. 9).—The usual brachycnemic condition is present in most; but in two specimens the mesenteries are brachycnemic on one side, and macrocnemic on the other. In most, fifteen perfect mesenteries occur on each side, and the same number of imperfect. In one, twenty-seven pairs in all were present, and in another twenty-eight pairs. Each has an irregularly shaped basal canal a little beyond the origin, and, in the upper part of the column, others extend almost across the mesentery. The basal canal is continued the whole length of the mesentery, and contains zooxanthellæ and large oval nematocysts; it may be divided in the upper part into two or more closely approximated canals.

The parieto-basilar muscles are well developed. Beyond the basal portion the mesenteries are very thin, and the endoderm is crowded with large zooxanthellæ. The imperfect mesenteries are very short proximally, appearing in transverse sections as goblet-shaped projections of the body-wall; the muscle extends all round, while the basal canal is more circular than in the others. The reflected ectoderm and mesenterial filaments are well developed.

Gonads (Pl. XVIII. A, fig. 8).—In one specimen examined, both male and female gonads were found in abundance; sometimes both kinds would occur on one mesentery, while others bore either ova or spermaria. The ova, which evidently were nearly ripe, were scarcely stained with borax carmine, while the spermaria readily took up the pigment.

Cœnenchyme.—In its outer part, the cœnenchyme has numerous inclosures similar to those of the body-wall. Many large cell inclosures and cœlenteric canals are met with, the latter with a very regular epithelial lining and a weak musculature.

Under their genus Gemmaria, MM. Duchassaing and Michelotti describe (1860) four species of Zoanthidæ from the Antilles, viz.:—*G. Rusei*, Duch. and Michel.; *G. clavata*, Duch.; *G. Swiftii*, Duch. and Michel.; and *G. brevis*, Duch. The first has been recovered in the Bermudas by McMurrich (1889), while *G. Swiftii* is shown in the present Paper to belong to the genus Parazoanthus.

I have hesitated considerably as to the identity of the present form with *G. clavata*, but have finally decided that the characters given in the two descriptions of it will not admit of this. The original diagnosis (1850, p. 11) gives the tentacles as about 30, and the later one (1860, p. 331) states the disc and tentacles to be violet.

The Jamaican form also appears to be a larger, more robust species. External characters readily separate it from *G. brevis*. *G. isolata*, described by M'Murrich, from the Bahamas (1889), is also evidently quite distinct. It can likewise be distinguished from the other known members of the genus—*G. Macmurrichi*, Hadd. and Shackl.; *G. Mutuki*, Hadd. and Shackl.; and *G. canariensis*, Hadd. and Duerd.—obtained from localities more distant.

Gemmaria fusca, n. sp.

(Pl. XVII. A, fig. 6.)

Form.—Polyps erect, firm, cylindrical, growing in colonies from a thin lamellar cœnenchyme or solitary; smooth above, with sand grains showing through the ectoderm, and scarcely any adhering particles, but many more below. Capitulum with about 30 ridges and furrows, may be slightly more or less; greatly expanded and overhanging in full extension. Tentacles dicyclic, smooth, acuminate, overhanging in extension, short, slightly entacmæous. Outer part of disc overhanging in full extension, giving an umbrella-like appearance, with the radiating mesenterial lines showing through; central portion of disc appears as a rounded elevation with the slit-like mouth at the apex, and is devoid of incrustations. Cœnenchyme spreading and closely incrusting the upper surface of rocks and stones, not very freely developed; exposed surface rough, due to adhering calcareous particles.

The individual polyps in a colony are usually closely apposed at the base, but may be separated a short distance from one another, or may ultimately become isolated. The polyps are practically the same diameter throughout, but may diminish a little below, expanding again towards the base. In retraction the distal part may be slightly swollen and rounded, with a central aperture; the number of capitular ridges, which extend for some distance down the column, is very variable. In preserved specimens the proximal part of the column is slightly wrinkled, but the distal is smooth.

Colour.—Distal part of column, tentacles, and disc dark brown; proximal part of column sand-coloured, often with foreign green matter; œsophagus white.

Dimensions.—Height of column varies from 1 to 3 cm., most are about 2·2 cm.; diameter 1 cm.; inner tentacles 0·15 cm. in length.

Locality.—Colonies and isolated individuals are found growing in considerable abundance attached to coral rock and stones in the very shallow water around

Drunkenman Cay; sometimes the polyps are partially embedded in sand and débris. Numerous young individuals arising directly from the cœnenchyme, or from the base of other polyps, are mingled with the older examples.

Column-wall (Pl. XVIII. A, fig. 10).—The ectoderm is continuous, and not much broken up by incrusting matter. The cuticle is thin, with few adhering foreign bodies. The ectoderm is broad in the distal part of the column, but narrows below, and the nuclei of the cells are uniformly distributed except near the cuticle, a regular columnar epithelium not being formed. Large oval nematocysts occur, and large zooxanthellæ are present in company with small narrow stinging cells and cells containing highly refractive pigment granules. The inner boundaries of the ectoderm are not well defined, and at the capitulum the layer becomes very thick and still more irregular in its internal outline; definite bays or growths into the mesoglœa appear in sections, probably due to the presence of capitular ridges and furrows.

The mesoglœa is of medium thickness, enlarging a little both proximally and distally; the incrustations are limited to the outer portion and the adjacent ectoderm. They occur very sparingly, not interfering with the cutting of thin sections, and consist of calcareous and a few siliceous sand grains, sponge spicules, and an occasional Foraminiferal or Radiolarian test. The mesoglœa contains isolated cells and cell-islets distributed with some uniformity, except in the lower part where an irregular zone of larger inclosures may be found a little nearer the inner boundary. The larger islets contain zooxanthellæ, large oval nematocysts, and occasionally pigment granules similar to those in the ectoderm, from which layer the cell-islets can be seen to originate.

The endoderm is thin, more so than in *G. variabilis*, and contains many zooxanthellæ. The circular endodermal muscle is well developed; fine fibrils from it stretch nearly across the mesoglœa, and others are seen connecting the various cells and cell-islets.

Sphincter muscle (Pl. XVIII. A, fig. 10).—The sphincter muscle is single and mesoglœal. It is long and situated near the endoderm. Proximally it commences in small irregular cavities in groups of two or three, and arranged in a not very regular row. The more distal cavities are much larger, irregular in form, and extend further across the mesoglœa; the muscle fibres are arranged obliquely, and isolated spherical cells occur. The muscle is shorter, the cavities less regular in arrangement, and not in such a single series as in *G. variabilis*; while the upper ones are closer, broader, and more irregular in outline.

Tentacles.—The ectoderm of the tentacles is very thick, and consists of an outer zone of small narrow nematocysts, and an inner zone of zooxanthellæ and nuclei irregularly arranged. A few pigment granules, a number of homogeneous deeply staining bodies, and glands filled with clear contents, are met with, and an occasional large oval stinging cell. Transverse sections show a well developed ectodermal muscle on mesoglœal plaitings. The mesoglœa has small cells scattered throughout. The endoderm is made up of small regularly arranged cells; an endodermal circular muscle is supported on fine mesoglœal plaitings; and zooxanthellæ are present.

Disc.—The ectoderm of the disc is even thicker than that of the tentacles, and exhibits an outer zone of clear gland spaces and small narrow nematocysts. The deeper part is largely composed of zooxanthellæ, glandular cells or spaces, and an occasional large oval stinging cell. An ectodermal muscle occurs on mesoglœal plaitings, and an endodermal muscle is present. The mesoglœa is thick and contains cells and cell-islets, but is devoid of incrustations.

Œsophagus.—Only a slight œsophageal groove is indicated, the mesoglœa being a little thickened and truncate, and the directives extend from the two corners. Below it is oval-shaped in section, and the ectoderm remains unfolded; distally the latter is thrown into eight or nine well marked folds on each side, only exceptionally followed by the mesoglœa. In a second specimen, the number of folds was fifteen on each side. Immediately on passing, in longitudinal sections, beyond the lips of the mouth, the ectoderm undergoes a great alteration from that of the disc. It is richly ciliated, a narrow zone immediately below is colourless; then follows a thick zone of narrow, closely-arranged nuclei, gland cells, and nematocysts, which together form a dense deeply staining band, extending the whole length of the œsophagus. A zone below this has only a few scattered nuclei, and, in places, the large oval stinging cells and pigment granules. The mesoglœa is a homogeneous layer with rarely an enclosed cell, and the endoderm is extremely thin. A weak endodermal but no ectodermal musculature occurs. Terminally the ectoderm is reflected upwards on the mesenteries for a short distance, and folded in a double pinnate manner, and then descends, constituting the mesenterial filaments.

Mesenteries.—The mesenteries are brachycnemic in arrangement. Twelve perfect pairs occur on each side in one specimen, and sixteen in another. In the middle œsophageal region each is extremely delicate, scarcely showing any enlargement towards the insertion at the body-wall or œsophagus; the usual basal canal is often absent, especially distally. The imperfect mesenteries are broad above, but very short below, not being readily distinguishable in places. The parieto-basilar muscle is present on each side; the retractor muscle is weak. A little beyond the insertion of the mesenteries is the flattened or oval-shaped basal canal filled with deeply-staining tissue, and now and then a large oval nematocyst. The endoderm is poorly developed, and has large zooxanthellæ.

Gonads.—No reproductive cells were present in the examples studied.

The combination of characters in which *Gemmaria fusca* differs from *G. variabilis* are: (1) the uniformly brown colouration, (2) the paucity of the incrustations, (3) the almost absence of basal canals in the upper part of the perfect mesenteries, (4) the appearance of the sphincter muscle, and (5) the generally more delicate structure throughout.

For some time I was inclined to regard these two species as being the same, and it was not until an anatomical examination had been made that their distinction was fully apparent. The sphincter muscle, quantity of incrustations, and other structures, are different. Externally they may be distinguished by their colouration. Though not inclined to regard this character as very constant, amongst numerous colonies I have met with no variations from the type in the present species, nor wholly brown examples of *G. variabilis*. *G. fusca* is longer and more regularly cylindrical than the other, without the same tendency to assume a clavate shape. It is also less rigid, the body-wall not being so thick and incrusted, and young individuals arise more numerously amongst the older polyps. The colonies are smaller and less associated.

Palythoa, Lamouroux, 1816.

Brachycnemic Zoantheæ with a single mesoglœal sphincter muscle. The body-wall is incrusted. The ectoderm is continuous. The mesoglœa contains numerous lacunæ, and occasionally canals. Diœcious. Polyps immersed in a thick cœnenchyme, which forms a massive expansion.

The above is the definition of the genus given by Haddon and Shackleton (1891, p. 691), who also add a detailed history of its complicated career.

In regard to the specific identification of its members, the genus Palythoa has always been recognized by specialists as one of extreme difficulty and uncertainty on account of its variability in form and the presence of only a few external diagnostic characters. Especially is this the case when, as usually obtains, its representatives are studied as alcoholic specimens in a condition of retraction and shrinkage in variable degrees. Great danger exists under these circumstances in the identification of isolated patches, or of even complete colonies. The external characters one has usually to depend upon are those of the amount of the column of the polyps free from the cœnenchyme, the dimensions, colour, wrinklings, number of capitular ridges and tentacles. All these are, however, very inconstant; only when a number of examples are obtainable for comparison can much value be placed upon them.

The height of the free portion of the column is mainly dependent upon the extent of retraction of the polyps, and is not a constant specific character. In one portion of a colony the upper surface may be almost uniform, none of the polyps being raised above the general level of the cœnenchyme; in another part the polyps may be quite free for a few millimetres. Again, colonies would be collected which became quite flat on their distal surface, due to excessive retraction as a result of rough handling; but, on coming to observe them later, the polyps had elevated the upper part of their column distinctly above the level of the cœnenchyme, and the whole presented a very different aspect. Such variations have also been noted as occurring on the same colony at one and the same time. The dimensions, especially the height of the column and cœnenchyme, are also very variable, depending largely upon the irregularities of the incrusted rock and the presence of contiguous colonies; one side of a colony may be two or three times the height of another.

The colour is so very similar in all the Jamaican forms I have examined as to be of little assistance. So far I have only met with various tints of yellow and brown; a colony which appears yellowish in the water may become brown on removal. Transverse and longitudinal wrinklings are largely determined by the amount of shrinkage in preservation; alcohol material showing more than formalin. The number of tentacles has been used by Duchassaing and Michelotti as an important aid in distinguishing species. Generally, this can only be of service where one is able to study the forms in the living condition, most colonies appearing to prefer a retracted state after removal from their natural habitat. I have generally found that unless much injured in removal, the polyps open out sufficiently for investigation during the first day in the laboratory, and plunging into formalin has fixed them in this condition. I have studied the capitular or marginal ridges more particularly when the polyps have been thus partially or completely open. In the numerous cases counted, the ridges were always found to correspond with half the total number of the tentacles, *i.e.*, with one cycle.

Although varying somewhat, there is no doubt that the ridges and tentacles are of considerable utility for systematic purposes. How far they may be depended upon will be seen from the following observations made specially upon numerous colonies from the various Cays to test the reliability of the character. Each of the letters indicates a separate colony, or portion of one, and the figures the number of ridges counted upon the individual polyps sufficiently open for the purpose.

Lime Cay:

A.—15, 13, 16, 16, 15, 15, 14, 15, 14, 16, 14, 15, 14, 16, 14, 15, 14, 14, 16.
B.—19, 20, 19, 20, 19.
C.—20, 19, 19, 20, 20.
D.—22, 19, 19.
E.—14, 14, 13, 14, 14, 15, 15.

South Cay:

F.—14, 14, 14, 14, 14, 15, 14, 16, 14, 16.
G.—18, 18, 18, 18, 19, 18, 18, 17, 19, 18, 18.
H.—18, 18, 19, 18, 18.
I.—18, 19, 18, 17, 19.

Drunkenman Cay:
J.—19, 18, 20, 18, 19, 19, 19, 20, 19, 19, 20, 20.
K.—17, 17, 19, 18, 18, 17, 18, 17.
L.—15, 20, 17, 16.

Gun Cay:
M.—14, 16, 15, 16, 15, 14, 15, 14, 17, 17, 14, 14, 16, 14, 16, 12, 12.
N.—14, 14, 16, 15, 14, 15, 16.
O.—16, 16, 17.
P.—16, 16, 16.
Q.—17, 16, 15, 14, 16, 14, 18, 16, 16, 14.

Maiden Cay:
R.—20, 18, 18, 16.
S.—18, 19.
T.—16, 16, 16, 17.

From these it will be seen that, in the series represented by B, C, D, G, H, I, J, K, R, S, the numbers vary from about 18 to 20, and in another, represented by A, E, F, M, N, O, P, Q, T, the numbers are roughly from 14 to 17. The average numbers of the capitular ridges of the two groups seem so constant and distinct that I have considered them of sufficient importance to justify a separation into the two accompanying species, and have found at the same time other distinctions which further support the conclusion. Although the genus occurs in such abundance around all the Cays, I have not found characters of sufficient stability to warrant the separation of more than these two species. Other diagnostic features will be discussed in dealing with their anatomy.

Palythoa mammillosa (Ellis and Solander).

(Pl. XVII. A, figs. 7, 8.)

Lapidis Astroitidis sive stellaris primordia,	Sloane, 1707, vol. 1, tab. 21, figs. 1–3.
Alcyonium mammillosum,	Ellis and Solander, 1786, p. 179, tab. 1, figs. 4, 5.
Palythoa mammillosa,	Lamouroux, 1816, p. 361, pl. xiii., fig. 2.
Palythoa mammilosa,	Milne-Edwards, 1857, p. 304.
Palythoa ocellata,	Duchassaing and Michelotti, 1860, p. 329.
Palythoa mamillosa,	Duchassaing and Michelotti, 1866, p. 140, pl. vi., fig. 10.
Palythoa cinerea,	Duchassaing and Michelotti, 1866, p. 141, pl. vi., fig. 8.
Polythoa mammillosa,	Andres, 1883, p. 332.
Polythoa (Corticithoa) cinerea,	Andres, 1883, p. 323.

Form.—Polyps smooth, rigid, cylindrical, arranged in a somewhat rectangular manner; the smooth ectoderm is easily rubbed off exposing the mesoglœa below, with a roughened surface due to the foreign incrustations; in retraction rounded or somewhat flattened above, free for a short distance beyond the surface of the cœnenchyme. In the living state, or when preserved in formalin without contraction, the polyps are equally free all round, and so closely arranged that they are separated above only by polygonal dividing lines, none of the cœnenchyme being visible (fig. 7). Specimens which have been preserved in alcohol and in which shrinkage has taken place are not equally free on all sides, but connected with one another by four (may be three or five when the polyps are not arranged in a rectangular manner) higher, occasionally grooved, ridges of cœnenchyme, and rounded depressions of cœnenchyme, are seen in the spaces between (fig. 8). A central, slightly depressed aperture remains in retracted polyps, and occasionally three to six longitudinal wrinklings along the free portion of the wall of the peripheral polyps are present in specimens preserved in alcohol, and also transverse wrinklings. The amount of the free portion varies according to the state of extension or retraction of the polyps in a colony. Usually in complete retraction about 0·4 cm. are free; in partial retraction, when the full capitular ridges can be counted, and in full expansion, about 0·6 cm. are free. In almost complete retraction the capitular ridges are wedge-shaped with very narrow furrows; as the polyps slowly open, the ridges become more convoluted or laterally undulating, and finally appear as so many acute marginal denticulations. These, as already shown above, are usually from 18 to 20 in number. The polyps of three other colonies from South Cay had a very regular number of ridges as follows:—

A.—19, 18, 18, 18, 18, 18, 18, 19, 18.
B.—19, 18, 18, 18, 18, 18, 18, 18, 19, 18, 19, 18, 19.
C.—18, 21, 18, 19, 18, 18, 18.

Tentacles very short, smooth, acuminate, dicyclic, inner row opposite the marginal denticulations, slightly entacmæous, overhanging in extension, 18 to 20 in each row. Disc cup-shaped in partial, and saucer-shaped in full, extension, but with the central part appearing as a dome and bearing the slit-like mouth at the apex. The peripheral zone of the disc is thin-walled, pellucid, smooth, devoid of incrustations, and raised into elevations and grooves corresponding with the number of tentacles, of which it appears as a continuation. In full extension it is flat or may be arched over; in partial extension it is nearly vertical. The central part of the disc is smooth, but contains a few incrustations. The species usually occurs in small, rather high colonies, closely associated with one another, but separated by deep channels. The incrusting base is much smaller in area than the distal surface, the peripheral polyps being arranged obliquely or radiately. New individuals arise mostly along the side of those forming the periphery of a colony.

Colour.—Cœnenchyme and column pale yellow or cream colour, sometimes brown; tentacles and furrowed portion of disc pellucid; middle of disc grey, due to presence of sand-grains; lips white.

Dimensions.—Average height of polyps 1·3 cm., may be only 0·6 cm. or 1·8 cm.; diameter of flat expanded disc 1·2 cm.; average diameter of columns 0·6 cm.; distance of centres of continguous polyps in retraction about 0·7 cm.; inner tentacles 0·2 cm. long. Colonies of various sizes are met with, but usually from 3 to 8 cm. across.

Locality.—Jamaica: found in abundance firmly encrusting the coral-rock in shallow water, mostly in the region of the breakers, at the Cays outside Kingston Harbour, and at other points around the coast.

Range.—Guadaloupe and St. Thomas (Duchassaing and Michelotti).

Column-wall (Pl. XIX., fig. 1).—The column-wall of the individual polyps is separable from the cœnenchyme for only a short distance at the upper surface of the colony. The two are not very thick compared with the size of the polyps. In transverse sections the cœnenchyme may be from 0·1 to 0·2 cm. in thickness, while the polyps are from 0·6 cm. to 0·3 cm. in diameter.

The ectoderm is a thick layer, and continuous over the outer surface of a colony; a cuticle, devoid of foreign adhering matter, is present. Its internal limitations are occasionally irregular, due to the incrusting sand-grains; these latter are limited to the inner part of the ectoderm and to the mesoglœa. The outer portion of the ectodermal cells is largely glandular; the middle and inner parts contain the nuclei, numerous zooxanthellæ, and occasional large oval colourless nematocysts showing the internal thread.

The mesoglœa varies in thickness, appearing in sections as a matrix in which the cylindrical polyps are embedded. The incrusting material is practically distributed throughout; in the periphery of a colony however it is rather limited to the outer half. The foreign objects are mostly calcareous, but a few siliceous sponge spicules and an occasional Foraminiferal and Radiolarian test may be present. Abundant small and large cell-islets or short canals are distributed with considerable uniformity; the latter in some sections exhibit somewhat of a concentric arrangement around the individual polyps, and may be seen communicating with the canals in the mesenteries. In others, a canal appears opposite nearly all the mesenteries. The islets contain zooxanthellæ and large oval nematocysts; the smaller islets have the protoplasm exhibiting peripherally a fine morula-like appearance, with a central more deeply staining nucleus. A similar condition is described under *Isaurus tuberculatus* (p. 347). Fine threads connect one group of cells with another.

The endoderm is a uniformly thin layer, and contains zooxanthellæ. A weak circular endodermal muscle is present.

Sphincter muscle (Pl. xix., fig. 1).—The sphincter muscle is single, mesoglœal, and contained in an elongated series of irregular cavities, situated near the endoderm; small cavities occur along with larger ones, all forming an irregular row.

Tentacles.—The ectoderm is very thick, consisting of an outer zone of small, elongated, narrow nematocysts, and an inner one with deeply-staining nuclei, zooxanthellæ, and pigment granules. The ectodermal muscle is well developed on mesoglœal plaitings. The mesoglœa in places is rather thick, and contains cell-islets. The endoderm is somewhat high, nearly filling up the lumen; the circular muscle is readily seen, forming a very regular layer in longitudinal sections.

Disc (Pl. xix., fig. 4).—The peripheral grooved portion of the disc has a very thick, highly glandular, sinuous ectoderm, containing zooxanthellæ, small peripheral nematocysts, and occasional deeper oval ones; also a well developed radial muscle. The mesoglœa follows the projecting fold, and becomes very thick, and may contain a few sand-grains; between the folds it is very thin. The endoderm is the same as elsewhere. In longitudinal sections of contracted specimens the part next the tentacles is thick; it then becomes delicate, and again enlarges towards the lips where incrustations occur in the mesoglœa. An endodermal muscle is present.

Œsophagus (Pl. xix., figs. 2, 3).—The œsophagus in different sections is either an elongate or a shortened pear-shape, with a well defined œsophageal groove. The ectoderm is richly ciliated; a zone of closely-arranged narrow nematocysts occurs peripherally, while the nuclei are arranged mostly in a middle zone; pigment matter occurs in the deeper parts, abundantly in some, sparingly in others. The ectoderm in most is thrown into folds which vary in number, but are generally between eight and eleven; in some sections the ectoderm is unfolded.

The mesoglœa is thin, becoming a little thicker at the groove; it does not follow the foldings of the ectoderm.

The endoderm is similar to that in the column-wall, but is slightly deeper between the mesenteries. It differs from that of the mesenteries in having little or no pigment matter.

Mesenteries (Pl. xix., figs. 2, 3).—The mesenteries in most cases present the usual brachycnemic type, but irregularities may occur, and opposite sides have not always the same number of pairs. The usual arrangement is that of ten perfect mesenteries on each side, but in one polyp there are ten on one side and nine on the other; in another seven and nine, arranged as shown in fig. 3. The fundamental distinction of the Zoanthidæ into Brachycneminæ and Macrocneminæ is departed from in the sections of two polyps represented. In fig. 2 it is seen that the normal brachycnemic arrangement holds on the left side, while the macrocnemic is present on the right side. This is also the case in fig. 3, only the order is reversed.

The manner of the connexion of the mesenteries to the œsophagus is best shown in fig. 2. Beyond the sulcar directives there is a considerable interspace before the other mesenteries are reached, and then the interspaces are about equal. The mesenteries are very thin near their attachment to the column-wall, but enlarge a little to form the basal canal. The imperfect mesenteries do not project far. The endoderm contains zooxanthellæ and pigment matter, and the mesoglœa is extremely thin. The parieto-basilar muscles are well developed. The basal canal is usually rounded, and contains numerous large oval nematocysts. The reflected ectoderm and mesenterial filaments present the usual structure. The digestive endoderm is very thick and granular.

Gonads.—No gonads were present in numerous examples sectionized.

Cœnenchyme.—The basal portion of the cœnenchyme is very crowded with canals in communication with the basal canals in the mesenteries and containing pigment granules and large oval nematocysts. Cœlenteric canals connect one polyp with another.

This species, first described by Ellis and Solander, is one of the two original representatives of the genus *Polythoa* of Lamouroux. The material upon which it was founded was originally obtained by Sir Hans Sloane from Jamaican waters, probably about the year 1687, when Sloane visited the island. The specimens were deposited by him in the British Museum; the collections of the famous naturalist and physician forming the nuclei of that national institution. Sloane, however, in his "Voyage," which deals largely with the Natural History of Jamaica, has no description of the objects beyond that given on the plate containing his three figures, "*Lapidis astroitidis sive stellaris primordia*," implying that this, along with the *Alcyonium ocellatum*, of Ellis and Solander, are the beginnings of the stony star-like corals, so abundant in the seas around.

Ellis and Solander first named, described, and again figured Sloane's specimen. Although their description, "This whitish leather-like Alcyonium is spread over rocks, with many convex teat-like figures, hollow in the middle, with a faint star-like appearance, and united close together," is rather incomplete for purposes of identification, still the excellent figure they give of a colony leaves me little hesitation in considering the form described above as the same these two authors had under consideration. The dimensions, amount of the polyps not immersed in cœnenchyme, and the general form of the colony well agree. I feel all the more assurance in this seeing that similar specimens may be collected in abundance from what we may regard as the original locality of the type. It is not at all improbable that Sloane obtained his examples from precisely the same Cays, these being, as already mentioned, the usual and most favourable spots for marine collectors.

Duchassaing and Michelotti (1860) describe as *P. ocellata* a form which, in their later paper (1866), they place under *P. mamillosa.* They also regard the *Corticifera flava* of Lesueur as a variety. It seems pretty evident that these authors, taking the number of tentacles as a criterion, introduced some little confusion, so that it is now very difficult, if not impossible, to ascertain what forms they are really describing.

There is nothing appearing in the original description and figure of *P. cinerea* which is not met with in the large amount of material of *P. mammillosa* which has come under my observation, the colour, form of the original polyps, and incrustations of the latter presenting all the variations ascribed to the former, while the number of tentacles exactly corresponds.

The species is readily distinguished *in situ* from the next one by its habit of growth, occurring mostly in numerous, closely associated, irregularly shaped, small, high colonies, separated by channels 2 or 3 cm. across. The colonies are usually from 8 to 10 cm. in diameter, but may be more. The individual polyps are also larger, and appear to open more readily and constantly, and to have a greater free distal portion.

The larger number of capitular ridges, tentacles, and corresponding mesenteries is evidently constant. The variations in transverse dimensions are more clearly indicated in sections. In the present species the diameter is often 0·6 cm., while in the next it is rarely more than 0·35 cm.

Histologically I have not been able to detect much specific difference. Numbers of sections have been examined from various colonies, some with the incrustations *in situ* and others decalcified. Although the incrustations are abundant and uniformly distributed throughout the colony, the mesoglœa is apparently not so crowded with them as in *P. caribœa.*

The basal canals appear more rounded, and perhaps the internal pigmentation is not so dense in the present example; also, as shown in the figure, the cavities of the sphincter muscle are not in such a regular row.

Palythoa caribæa, Duchassaing and Michelotti.

(Pl. xvii. a, fig. 9.)

Palythoa caribæorum, . . Duchassaing and Michelotti, 1860, p. 329.
Palythoa caribæa, . . . Duchassaing and Michelotti, 1866, p. 141, Pl. vi., fig. 11.
Polythoa (*Monothoa*) *caraibeorum*, Andres, 1883, p. 322.

Form.—Polyps smooth, rigid, cylindrical, closely associated and arranged in an irregular manner, usually free from the cœnenchyme for a short distance, free portion rounded or conical in retraction; in very strong retraction, the upper surface of the colony may be nearly flat; no wrinklings in specimens preserved in formalin. Capitular ridges and furrows variable, usually from 14 to 17. The following numbers counted on two colonies will indicate the amount of this variation:—

A.—15, 14, 16, 15, 14, 16, 14, 16, 15, 15, 15, 15, 14, 15, 15, 15, 15, 15, 15, 16, 15, 14, 16, 16, 17, 16, 17, 15, 14, 17, 15, 15.

B.—14, 18, 16, 14, 17, 15, 17, 17, 15, 17, 14, 15, 15, 14, 15, 14, 16, 15, 16, 16, 16, 16, 16, 17, 17.

Tentacles dicyclic, smooth, pellucid, very short, acuminate, slightly entacmæous, inner row opposite capitular ridges, overhanging in full extension, vary from 28 to 34 in number. Disc considerably depressed in partial extension, overhanging in full extension, cup-shaped or saucer-shaped, according to amount of extension; divisible into two portions: an outer, thin, transparent, non-incrusted, circular area with rounded ridges and furrows corresponding to the number of tentacles, and a dome-shaped central portion, with a few minute incrustations, and bearing the slit-like mouth at the apex.

The polyps are arranged very closely, and the amount of cœnenchyme connecting the individuals is thin. At the periphery of the colonies, the outlines of the different marginal polyps are clearly indicated. New individuals appear to arise between previously existing ones. The colonies are usually very extensive, irregular in outline, and often incrust very uneven surfaces, the height of the polyps varying accordingly, so as to produce a regular undulating surface above.

Colour.—In the living condition, a pale yellow or cream colour, or sometimes brown, white when the ectoderm is rubbed off, lips white. In specimens preserved in formalin a curious change is effected. Nearly the whole of the upper surface of the colony may become a brick-red colour. The capitular ridges, however, for some distance down the column, are quite colourless and hence readily counted. The tentacles, inturned disc, and edges of the mesenteries are likewise altered in colour.

Dimensions.—The length of the polyps and the thickness of the cœnenchyme differ very much, may vary from 0·3 or 0·4 cm. to 1·8 cm., usually about 0·7 cm.; diameter of disc in partial extension 0·5 cm., in full extension 0·9 cm., in retraction 0·4 cm.; distance of centres of contiguous polyps 0·5 cm.; height of free portion above the level of the cœnenchyme in partial retraction about 0·5 cm.; tentacles about 0·2 cm. long; diameter of polyps in section 0·35 cm.

Activities.—Quantities of bubbles of gas are given off when the colonies are exposed in the water to the direct rays of the sun. The polyps do not appear to open so readily as in *P. mammillosa.*

Locality.—Jamaica: Numerous colonies form flat expansions covering considerable areas of coral rocks, at all the Cays outside Kingston Harbour.

Range.—St. Thomas (Duchassaing and Michelotti).

Column-wall (Pl. XIX., fig. 5).—The lower boundary of the column-wall of the individual polyps in a colony can not be distinguished from the cœnenchyme in which the polyps present the appearance of being embedded, but above it is quite distinct. The ectoderm is continuous, and spreads as a uniform layer over the surface of the whole colony; a thin, well defined cuticle occurs on the outside. It is not readily separable from the mesoglœa, appearing to pass insensibly into the cell-enclosures of the latter; narrow elongated nematocysts occur, as well as very large oval nematocysts, which do not stain; zooxanthellæ are present; foreign incrusting material is met with only in the deeper part of the ectoderm.

The mesoglœa is densely crowded throughout its whole thickness with calcareous sand-grains; a few siliceous sponge spicules, Radiolarians, and rarely a Foraminifera occur; most of the material can be dissolved out by acids. Isolated cells and large and small cell-islets are scattered throughout; the large nematocysts, pigment granules, and densely staining tissue fill up the islets.

The endoderm is very thin and uniform in height, except in the upper region where the mesenteries are closer, when the endoderm elongates in the middle and appears triangular in section. It contains abundant granular pigment matter and zooxanthellæ; a weak endodermal muscle is present on slight plaitings of the mesoglœa, especially in the upper region.

Sphincter muscle (Pl. XIX., fig. 5).—The single sphincter muscle is contained in a very regular series of small mesoglœal cavities; proximally they are situated close to the endodermal border, but are more central above, where also the cavities are not in such a single series and become a little larger. The muscular lining is thick, but does not quite fill the cavities.

Tentacles.—The tentacles have a very broad ciliated ectoderm crowded with narrow elongated nematocysts, zooxanthellæ, and pigment granules; the mesoglœa and the endoderm are thin. The longitudinal ectodermal muscle is well developed on small mesoglœal plaitings.

Disc.—The ectoderm of the disc is broad and contains nematocysts, zooxanthellæ, and pigment granules in the deeper parts. The mesoglœa thickens towards the middle, and incrustations are there present. The endoderm is like that of the column-wall.

Œsophagus.—The outline of the œsophagus varies in different regions and in different specimens. In most polyps it is the usual pyriform, truncated shape, with the ectoderm thrown into seven or eight longitudinal folds on each side, and the œsophageal groove well marked and occupying nearly one-third of the transverse diameter; but in others, it may be almost circular in outline with none of the folds showing. The ectoderm is very thick, stains deeply, is richly ciliated, and loaded internally with yellow pigment granules, and outwardly with elongated nematocysts. The mesoglœa is narrow, thickening a little at the groove; the endoderm is like that of the column-wall.

Mesenteries (Pl. XIX., fig. 7).—The mesenteries present the usual brachycnemic arrangement in most cases; but, as already mentioned, irregularities may occur, so that a polyp may be brachycnemic on one side and macrocnemic on the other, while one polyp has been met with which has the latter arrangement on both sides. The number of pairs is variable, and the two lateral halves do not always correspond. In a portion of one colony two polyps have eight perfect mesenteries on each side; two have eight on one side and seven on the other; while another has six on one side and eleven on the other. The imperfect mesenteries are well developed. The endoderm is very thick, and contains zooxanthellæ, nematocysts, and abundant pigment matter. The parieto-basilar muscle is clearly seen on each side, but the retractor muscle layer is scarcely distinguishable. The mesoglœa is extremely thin, except towards the column-wall, where the canals or sinuses extend nearly the whole vertical length; they occupy almost the whole transverse width in the uppermost region, but are elongated or oval below. The basal canals are well developed in both the perfect and imperfect mesenteries, and are crowded with oval nematocysts and pigment particles, and connected below with the sinuses in the cœnenchyme. The ectoderm of the œsophagus is reflected and folded on the mesenteries. The endoderm on the lower part of the mesenteries is enormously thickened and loaded with granules; the mesenterial filaments become nearly circular.

Gonads (Pl. XIX., fig. 6).—Spermaria, arranged in vertical and transverse rows, were present in the mesenteries of some of the polyps examined.

I identify the abundant Jamaican material with Duchassaing and Michelotti's species, mainly from the number of tentacles which these authors give, viz., thirty to thirty-two; these coming nearest to those indicated above. The figure which they give is of a dried specimen with all the polyps withdrawn to their full extent.

At first I considered it to be *Alcyonium ocellatum*, Ell. and Sol., obtained along with *A. mammillosum* by Sloane from Jamaica, there being nothing in the original descriptions and figures which is not met with in the specimens I have examined. McMurrich has, however (1889, p. 120), appropriated this name for some small colonies from Shelley Bay, Bermudas. He does this upon very slender grounds, this being the name given it by the collector. He has very kindly compared the Jamaican examples with those from the Bermudas, and states that they are quite different, especially in their anatomical characters, although acknowledging that it would seem as if they were the true *P. ocellata.* Under the circumstances, however, it seems best that McMurrich's identification should stand, and to allocate Duchassaing and Michelotti's name, with which the material very closely agrees. Andres (1883, p. 323) is evidently acting contrary to these two authors in considering the *Hughœa caraibeorum* of Duchassaing as a synonym of this species, as, in the "Mémoire" (p. 315), they place it in the genus Paractis.

In a quantity of colonies, it can easily be separated from *P. mammillosa*, not only by the average number of capitular ridges and tentacles, but by the differences in size of the polyps, those of the present species being smaller and more closely aggregated than the former. Usually the colonies are flatter, and cover larger areas. The polyps generally retract to a greater degree, so that the upper surface of the colony becomes more uniform.

Sub-family.—MACROCNEMINÆ.

Epizoanthus, Gray, 1867.

Macrocnemic Zoantheæ, with a single mesoglœal sphincter muscle. The body-wall is incrusted. The ectoderm is usually continuous, but may be discontinuous; cell-islets in the mesoglœa. Diœcious. Polyps connected by cœnenchyme, which may be band-like, incrusting, or greatly reduced, as in the free form.

The genus *Epizoanthus* is defined as above by Haddon and Shackleton (1891, p. 632) accompanied by a full account of its history. They recognize twelve species from various parts of the world, and four doubtful forms. Some of the representatives of the genus form incrustations over the surface of univalve shells inhabited by hermit-crabs, the shells being ultimately dissolved away. The colony, known as a carcinæcium, retains somewhat the form of the shell, and contains the crustacean still within.

Epizoanthus minutus, n. sp.

(Pl. XVII. A, fig. 10.)

Form.—Polyps cylindrical, rising obliquely or vertically from a thin, incrusting, ribbon-like cœnenchyme. In complete retraction rounded above with a small aperture remaining, but no capitular ridges and grooves distinguishable. Slightly enlarged towards the base; about the same height as breadth in retraction, not much more in extension; surface rough, covered with very fine sand grains; occasionally with slight transverse wrinklings. In partial retraction swollen and flat above, with the wedge-shaped, acute, capitular ridges and furrows visible, and the slit-like mouth showing. In full extension the upper part of the column is spread out and the middle constricted; margin of column with fifteen or sixteen or twenty-one denticulations, each with parallel sides and a straight free edge, giving a castellated appearance. Disc much depressed, cup-shaped, transparent, with lines of attachment of mesenteries showing through; mouth elevated. The disc, as usual, is divisible into a grooved outer part forming the walls of the cup in extension, and appearing as a continuation of the united bases of the tentacles, and an inner, smooth, flat or slightly elevated, central part bearing the mouth in the middle. Tentacles dicyclic, thin, transparent, elongated, slightly swollen and rounded at the tips, outer series alternating with the denticulations, entacmæous, overhanging in extension, generally thirty or thirty-two in number, but occasionally forty-two. Cœnenchyme thin, incrusting, ribbon-shaped or irregularly expanded where the polyps are closer; surface same as that of column-wall. Polyps arise independently, and may be considerably separated or more closely grouped.

Colour.—Column-wall and cœnenchyme are a dirty brown, the colour of the sand particles; denticulations with white margins; disc brown, with darker radiating lines; tentacles transparent, several series of dark patches are present, more pronounced on the outer row, tips almost opaque white.

Dimensions.—Height of polyps in extension 0·6 cm., in contraction 0·35 to 0·2 cm. Diameter in extension 0·3 cm., in retraction 0·25 to 0·2 cm. Length of tentacles in full extension 0·4 cm.

Locality.—Found growing in abundance near the margin of one of the valves of a living Pinna shell, collected towards the eastern extremity of Kingston

Harbour in water of not more than half a fathom in depth, and only a few yards from the shore. The polyps are very sensitive and active, retracting immediately on being touched.

Column-wall (Pl. xx., figs. 1, 2).—The outline of the column-wall, owing to the presence of incrusting material, is very irregular in sections, especially in the lower part; in the region of the marginal denticulations it is sinuous, and thicker, and the incrusting matter is aggregated opposite the inner circle of tentacles. Where perfect, the ectoderm is continuous; in most places, it is broken up or absent. It is covered on the outside by a cuticle with an adhering layer of foreign material, mostly diatom frustrules and fine mud.

The mesoglœa varies in thickness, being much better developed proximally. It contains isolated cells with long processes, cell-islets, and irregular communicating canals. The incrustations are sparsely distributed, and are mostly siliceous sand grains and a few sponge spicules.

The endoderm is very thin and regular, and the transverse muscle is well developed.

Sphincter muscle (Pl. xx., fig. 1).—The single mesoglœal sphincter muscle is small, and formed in a few, irregular, closely set cavities, extending about half way across the mesoglœa, and situated just at the base of the outer row of tentacles. The lining muscle-fibres are weak, and other rounded cells partially fill up the cavities.

Tentacles (Pl. xx., figs. 2, 3).—The ectoderm of the tentacles is thick compared with the two other layers, and the ectodermal muscle is well developed on small mesoglœal plaitings; numerous small oval nematocysts occur, and pigment granules in places. The nervous layer is clearly distinguished between the nucleated zone and the muscle fibres, and sends connecting strands to each. The mesoglœa and endoderm are both very thin. An endodermal muscle layer is present, seen in longitudinal sections.

Disc (Pl. xx., fig. 2).—The structure of the disc is much like that of the tentacles, but the ectoderm is not so well developed, and its outer grooved portion is in places loaded with pigment granules.

Œsophagus.—In extended specimens the œsophagus is almost circular in outline; the œsophageal groove is quite shallow. In longitudinal sections the wall is thrown into transverse folds. The ectoderm is a very regular, ciliated layer, with abundant gland-cells and a few small nematocysts; pigment granules occur in the deeper parts; it is reflected above the lower termination of the œsophagus, and below forms the mesenterial filaments in the usual manner. The mesoglœa and endoderm are very thin, especially the latter.

Mesenteries (Pl. xx., fig. 4).—Sixteen pairs of mesenteries, presenting the usual macrocnemic arrangement, occur in one specimen, and are all very thin except near their origin and where fertile; the imperfect are very short; the parieto-basilar muscle is developed along each side; no basal canals, or only traces of them, are present. The mesenterial muscles are seen on slight plaitings; pigment granules occur in groups on the endoderm. The digestive endoderm is thick, and large oval nematocysts are embedded in it, along with groups of pigment granules. The imperfect mesenteries have the muscle fibres extending all round. In the distal region, just below the œsophagus, the mesoglœa at the origin of the mesenteries is rectangular, but proximally it becomes goblet-shaped, the part produced beyond in perfect mesenteries being extremely thin. Proximally the mesenteries are branched.

Gonads (Pl. xx., fig. 4).—Spermaria apparently enclosed in endoderm were met with in abundance in two specimens.

This species is most closely allied in outward appearance to the well known European *Epizoanthus Couchii* (Johnston), Hadd. and Shackl. Obvious differences occur in the number and form of the capitular denticulations, the Antillean representative having fifteen, sixteen, or twenty-one, truncated at their free edge; while the older species has twelve or fourteen triangular teeth. The tentacles differ in a corresponding manner. Histological characters indicate further distinctions. It is readily separated from the seven other species examined by the two authors mentioned above, and also from the "Challenger" species. Of American forms it appears to bear a close relation to the incompletely described *Epizoanthus humilis*, Verr. (1869), from Panama.

Parazoanthus, Haddon and Shackleton, 1891.

Macrocnemic Zoantheæ, with a diffuse endodermal sphincter muscle. The body-wall is incrusted. The ectoderm is continuous. Encircling sinus as well as ectodermal canals, lacunæ, and cell-islets in the mesoglœa. Diœcious. Polyps connected by thin cœnenchyme.

This genus, with the above definition, was established by Haddon and Shackleton (1891, p. 653), to include macrocnemic Zoantheæ with a diffuse endodermal muscle, forms which previously had been referred by Hertwig and Erdmann (1888, p. 35) to the genus *Palythoa.* The authors recognize five species examined by them, and two described by Hertwig and Erdmann. The combination of anatomical characters renders it a well-defined genus.

Carlgren (1895) has shown that the genus *Gerardia*, Lac.-Duth., formerly included, with some hesitation, amongst the Antipatharia, is closely allied to the present genus, differing only in the presence of a strongly developed horny skeleton.

Parazoanthus Swiftii (Duchassaing and Michelotti).

(Pl. xvii. a, fig. 11.)

Gemmaria Swiftii, . . .	Duchassaing and Michelotti, 1860, p. 331, pl. viii., figs. 17, 18: 1866, p. 138.
Polythoa (str. s.) axinellæ,	Andres, 1883, p. 311, pl. x., fig. 7.

Form.—Polyps very short, cylindrical, mammiform in retraction, erect, firm, smooth, rising from small band-like branching patches of cœnenchyme incrusting the surface of a sponge; sometimes the polyps are arranged in a single linear series, at other times the cœnenchyme is expanded, and two or three individuals may occur abreast. Capitulum with twelve serrations at the apex. In partial retraction these appear as so many wedge-shaped ridges, with intervening furrows, around a central orifice; in full retraction the capitular ridges are scarcely visible, and the polyps are rounded above.

Tentacles minute, entacmæous, acuminate, dicyclic, twelve in each row, the outer alternating with the serrations, overhanging in extension. Disc concave, transparent, with mesenteries showing through; mouth slit-like and capable of considerable eversion; lips crenate; œsophagus shows longitudinal mesenterial lines; oral cone may be considerably elevated. The usual condition of the polyps appears to be that of retraction.

The cœnenchyme is smooth, thin, in irregularly shaped meandering ribbons or patches firmly incrusting and partially embedded in the sponge.

Colour.—Cœnenchyme and column-wall are a bright orange yellow, lighter on the upper part of the column; tentacles are pale yellow; disc a darker, and lips a bright yellow. The parts are sand-coloured where the ectoderm is rubbed off. The bright orange colour gives to the colonies a marked contrast with the dark green sponge.

Dimensions.—Height of polyps above the cœnenchyme varies from 0·15 cm. to 0·3 cm.; diameter of expanded disc 0·4 cm.; diameter of column in contraction 0·2 cm.

Locality.—Jamaica: Obtained growing in small colonies on a large, erect, blackish-green, branching sponge collected in water of about two fathoms around Rackum Cay; also from the shallow waters S. W. of Lime Cay, living on the same species of sponge.

Range.—St. Thomas (Duchassaing and Michelotti).

Column-wall (Pl. xx., fig. 5).—The column-wall is very thick. The cuticle is well defined; the ectoderm continuous and variable in height, with irregular internal limitations. Excepting a narrow zone immediately below the cuticle, the ectoderm cells are crowded with abundant yellow pigment granules of various sizes and numerous medium-sized, oval, colourless nematocysts. It is practically free from inclosures, these being limited to the mesoglœa.

The mesoglœa shows a very marked division into two parts. The outer is a thick layer of variable dimensions, and crowded with foreign inclosures and abundant yellow pigment granules, limited internally by the encircling sinus. This latter is broken here and there by strands of mesoglœa, and has very irregular limitations; the cavities are filled with deeply staining tissue and pigment. The inner layer of the mesoglœa is clear and nearly homogeneous, devoid of incrustations and pigment granules, and plaited internally to support the endodermal muscle. The incrusted part in retracted specimens is enlarged a little below the middle of the column, and contains cell-enclosures. The incrustations consist of siliceous and a few calcareous sand grains, and sponge spicules. The mesoglœa is too crowded with incrustations and pigment matter to allow of any connecting canals which may be present between the ectoderm and the encircling sinus being distinguished.

The endoderm cells are high, especially between the mesenteries, and contain abundant yellow pigment spheres and granules; a little below the middle of the column, they give rise to a well developed circular endodermal muscle supported on folds of the mesoglœa.

Sphincter muscle (Pl. xx., fig. 5).—The sphincter muscle is diffuse and endodermal, and formed as a greater concentration of the ordinary endodermal muscle of the column-wall. Distally it is so deeply sunk in the folds of the mesoglœa that in some sections it appears to be entirely cut off from the endoderm, and to become a mesoglœal muscle enclosed in separate cavities.

Tentacles.—In transverse sections of retracted polyps, the tentacles are so closely arranged as to become polygonal in outline. The ectoderm is thick, and has an outer zone of narrow nematocysts capable of staining; below is an irregular zone of pigment granules. An ectodermal muscle on slight mesoglœal plaitings is seen in transverse sections. The mesoglœa is only a thin layer, and internally is thrown into folds for the support of the circular endodermal muscle.

The endoderm has abundant pigment spheres and fills the lumen in contraction. The distinction between the granular pigment matter in the ectoderm and the spherical form in the endoderm, although of the same colour, is very marked. A similar difference is found in the ectoderm and endoderm of the column, but not to such a degree as in the tentacles. All the three layers of the disc are but little developed, presenting a marked contrast to the tentacles.

Œsophagus.—The ectoderm of the œsophagus is richly ciliated and folded; the deeply staining nuclei are arranged in a middle zone; narrow nematocysts occur and large deeply staining granular gland-cells. The mesoglœa is very narrow. The endoderm is thick and crowded with pigment spheres. A sulcar groove occurs, and here the mesoglœa is much thickened, but contains no cell-enclosures.

Mesenteries (Pl. xx., fig. 6).—Twelve pairs of mesenteries, macrocnemic in their arrangement, are present. In the upper region each is a little narrow at its insertion in the column-wall, but the mesoglœa thickens rapidly; only for a short distance in the œsophageal region, but more below. In the perfect mesenteries, the mesoglœa beyond is very thin, and appears to alter in character so that it takes the stain better. There are no basal canals nor any cell-enclosures in the upper region; but lower two or three short canals, or there may be only cell-enclosures with pigment granules, appearing in the thickened part of the mesenteries. The endoderm is like that of the column-wall. Below the œsophagus it thickens enormously, and contains much pigment and granular matter; the mesenterial filaments are well developed and branched. In these, the zone of nuclei stains deeply, and occasional very deeply staining glandular cells are present along with nematocysts and much pigment matter. The parieto-basilar muscle is well marked on each side of the mesentery, extending a very little along the column-wall. In the imperfect mesenteries, the musculature extends the whole way round; in the perfect mesenteries, scarcely any distinction can be made in the musculature of each side, and the mesoglœa is finely plaited.

Gonads (Pl. xx., fig. 6).—All the specimens examined from one colony contained abundant ova, present only on the perfect mesenteries, and associated with much pigment matter and enormously thickened endoderm.

Cœnenchyme and *Base* (Pl. xx., fig. 5).—The proximal surface of the base and cœnenchyme, in contact throughout with the sponge, has a thin ectoderm crowded with yellow pigment granules. The ectoderm of the upper surface of the cœnenchyme is thick, and resembles that of the column-wall.

The mesoglœa is rather thick, and its inclosures are similar to those of the column-wall, but with a larger proportion of sponge spicules; cell-inclosures are numerous, and contain pigment granules. The endoderm of the base of the polyp is very thin, and contains pigment spheres and granules.

This species was first described by Duchassaing and Michelotti from specimens obtained at St. Thomas. Of their figures (references to which are omitted from the "Explication des Planches"), fig. 18 gives an approximate representation of the appearance of the colonies on the sponge; but fig. 17 is probably erroneous in the number and appearance of the capitular ridges and furrows indicated. Eight of these are shown, while in every case I have found twelve. In their later paper (1866, p. 138) they state the number of tentacles to be twenty-four, and arranged in two series; and it is generally found that the capitular radiations correspond in number with one series of the tentacles. Andres (p. 311) regards the species as synonymous with *Polythoa axinellæ*, Schmidt. This has since been described by Haddon and Shackleton (1891, p. 654), who make it the type species of the present genus. It will be found from the account here given, that the West Indian representative differs from the description of the European example, likewise commensal with a sponge, in many features both of form and anatomy.

The extraordinary abundance of the bright yellow pigment granules throughout the ectoderm and endoderm should be noted in the present species.

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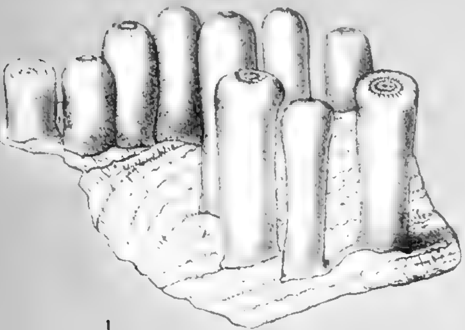
EXPLANATION OF PLATE XVII. A.

PLATE XVII. A.

Figure.

1. *Zoanthus Solanderi*, Les. (p. 335). Drawn from formalin material.
2. *Zoanthus flos-marinus*, Duch. and Michl. (p. 339). Drawn from formalin material.
3. *Zoanthus pulchellus* (Duch. and Michl.), (p. 341). Drawn from formalin material.
4. *Isaurus Duchassaingi* (Andres), (p. 346). Drawn from formalin material.
5. *Gemmaria variabilis*, n. sp. (p. 350). Drawn from alcohol material.
6. *Gemmaria fusca*, n. sp. (p. 354). Drawn from formalin material.
7. *Palythoa mammillosa* (Ell. and Sol.), (p. 359). Drawn from formalin material.
8. *Palythoa mammillosa* (Ell. and Sol.), (p. 359). Drawn from alcohol material.
9. *Palythoa caribæa*, Duch. and Michl. (p. 365). Drawn from formalin material.
10. *Epizoanthus minutus*, n. sp. (p. 369). Drawn from life.
11. *Parazoanthus Swiftii* (Duch. and Michl.), (p. 372). Drawn from formalin material.

The dimensions represented are practically the same as in the living condition.



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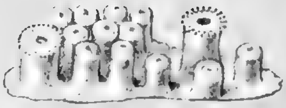

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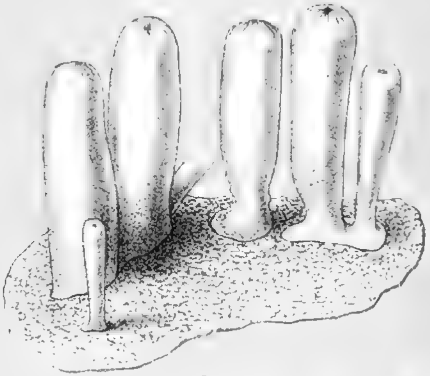

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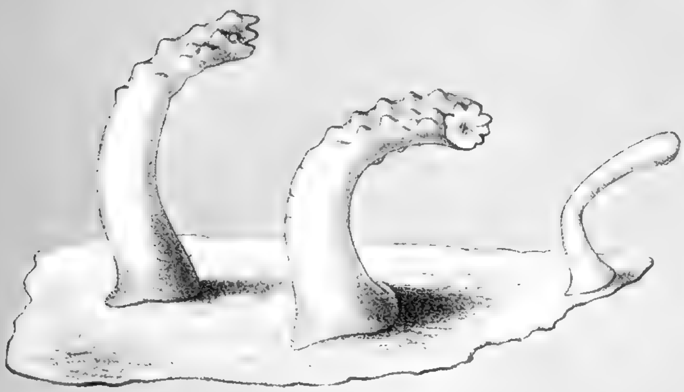

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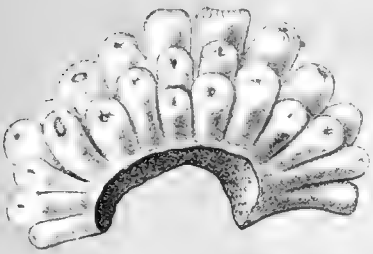

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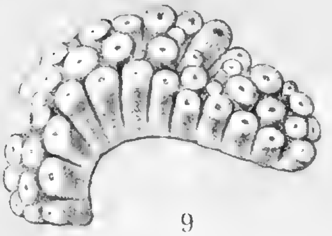

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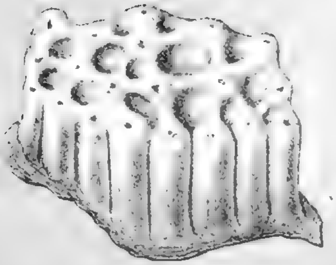

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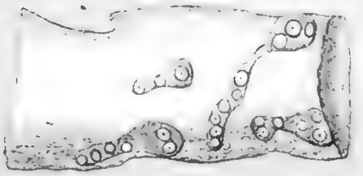

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[illegible] Wilson Cambridge.

EXPLANATION OF PLATE XVIII. A.

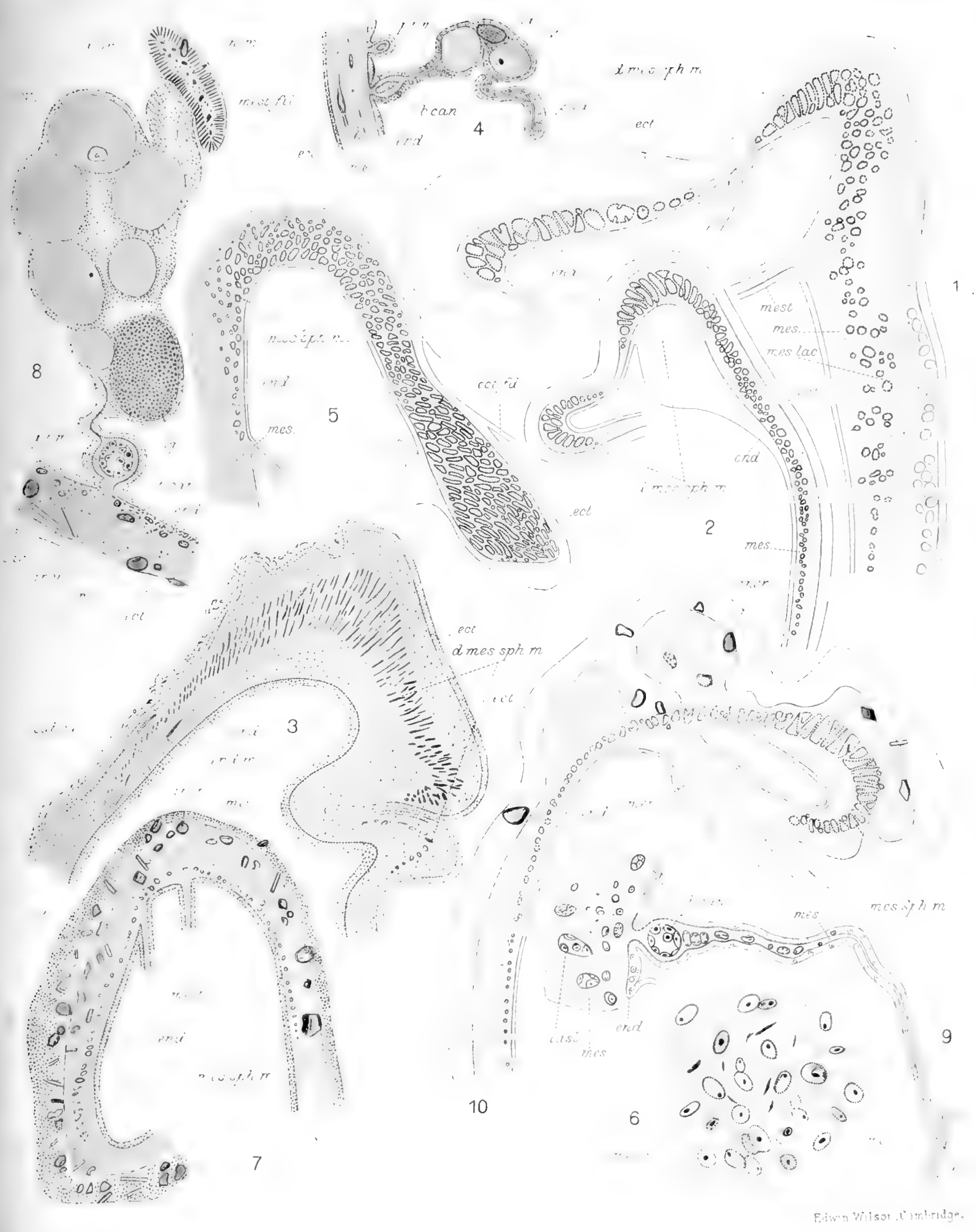
PLATE XVIII. A.

LETTERING ON THE FIGURES.

b. can.,	basal canal.	*mes. sph. m.,*	mesoglœal sphincter muscle.
c. isl.,	cell-islets.	*mes. c.,*	mesoglœal cells.
ect.	ectoderm.	*mes. lac.,*	mesoglœal lacunæ.
ect. fd.,	ectodermal folds.	*p. b. m.,*	parieto-basilar muscle.
d. mes. sph. m.,	double mesoglœal sphincter muscle.	*nem.,*	nematocysts.
end.,	endoderm.	*ov.,*	ovum.
end. m.,	endodermal muscle.	*œs.,*	œsophagus.
incr.,	incrustations.	*p. gr.,*	pigment granules.
mes.	mesoglœa.	*sub-cu.,*	sub-cuticla.
mest.,	mesentery.	*sp.,*	spermarium.
mest. fil.,	mesenterial filament.	*zoox.,*	zooxanthellae.

Figure.

1. *Zoanthus Solanderi*, Les. (p. 335). Vertical section through a portion of the column-wall, × 50.
2. *Zoanthus flos-marinus*, Duch. and Michl. (p. 339). Vertical section through a portion of the column-wall, × 50.
3. *Zoanthus pulchellus* (Duch. and Michl.), (p. 341). Vertical section through a portion of the column-wall, × 200.
4. *Zoanthus pulchellus* (Duch. and Michl.), (p. 341). Transverse section through a portion of the column-wall and a fertile mesentery, × 50.
5. *Isaurus Duchassaingi* (Andres), (p. 346). Vertical section through the upper portion of the column-wall, × 25.
6. *Isaurus Duchassaingi* (Andres), (p. 346). Section through a portion of the mesoglœa of the body-wall, showing cells with peripheral granular protoplasm, × 250.
7. *Gemmaria variabilis*, n. sp. (p. 350). Vertical section through a portion of the column-wall, × 25.
8. *Gemmaria variabilis*, n. sp. (p. 350). Transverse section through a portion of the column-wall and a fertile mesentery, × 200.
9. *Gemmaria variabilis*, n. sp. (p. 350). Transverse section through a portion of the column-wall and a perfect mesentery in the region of the œsophagus, × 50.
10. *Gemmaria fusca*, n. sp. (p. 54). Vertical section through a portion of the column-wall, × 40.



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EXPLANATION OF PLATE XIX.

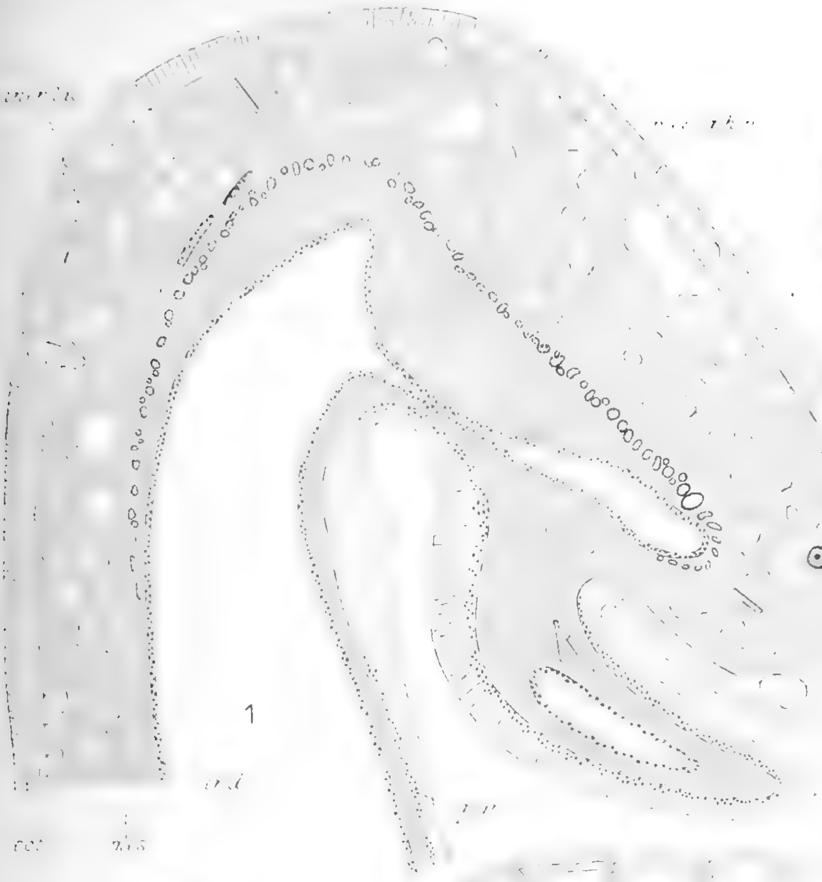
PLATE XIX.

LETTERING ON THE FIGURES.

b. can.,	basal canal.	*mest. fil.*	mesenterial filament.
br. m.,	brachycnemic mesentery.	*mes. sph. m.*,	mesoglœa sphincter muscle.
c. isl.,	cell-islets.	*mr. m.*,	macrocnemic mesentery.
ect.,	ectoderm.	*œs.*,	œsophagus.
ect. m.,	ectodermal muscle.	*œs. gr.*,	œsophageal groove.
end.,	endoderm.	*p. gr.*,	pigment granules.
incr.,	incrustations.	*s. d.*,	sulcar directive mesenteries.
incr. lac.,	lacunæ produced by removal of incrustations.	*sl. d.*,	sulcular directive mesenteries.
		sp.,	spermaria.
mes.,	mesoglœa.	*t.*,	tentacles.

Figure.

1. *Palythoa mammillosa* (Ell. and Sol.), (p. 359). Vertical section through a portion of the upper free part of a polyp, from which most of the incrustations have been dissolved, × 50.
2. *Palythoa mammillosa* (Ell. and Sol.), (p. 359). Transverse section through the œsophageal region (diagrammatic), × 35.
3. *Palythoa mammillosa* (Ell. and Sol.), (p. 359). Transverse section through the œsophageal region of a younger polyp (diagrammatic), × 35.
4. *Palythoa mammillosa* (Ell. and Sol.), (p. 359). Transverse section through a partially extended polyp, passing through a portion of the grooved part of the disc, × 50.
5. *Palythoa caribæa*, Duch. and Michl. (p. 365). Vertical section through a portion of the upper free part of a polyp, × 50.
6. *Palythoa caribæa,* Duch. and Michl. (p. 365). Transverse section through a fertile mesentery, × 50.
7. *Palythoa caribæa,* Duch. and Michl. (p. 365). Transverse section through the œsophageal region (diagrammatic), × 35.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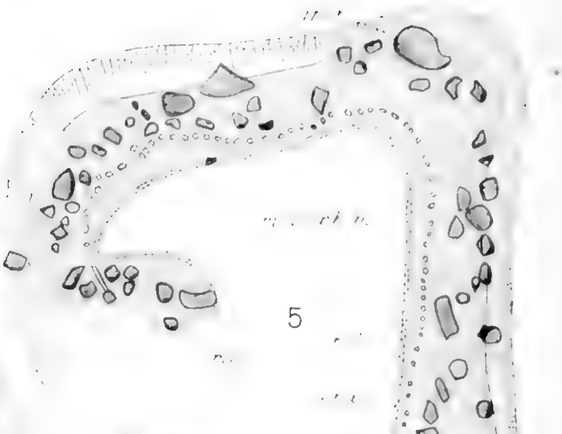
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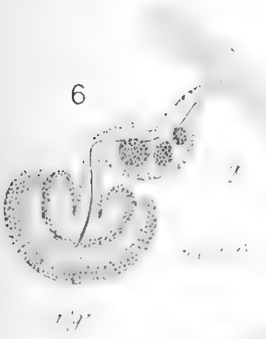
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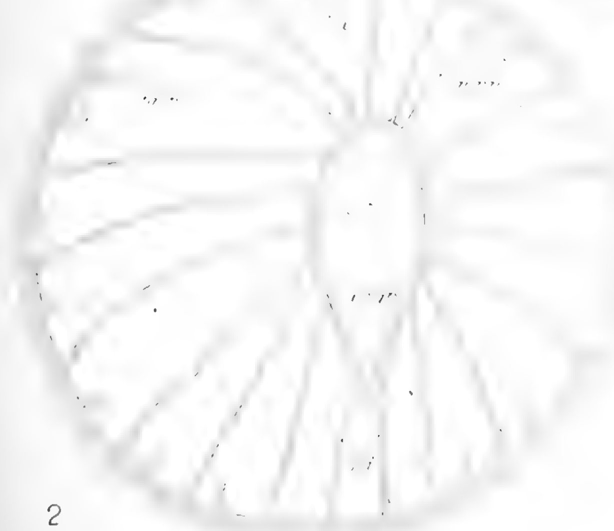
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EXPLANATION OF PLATE XX.

PLATE XX.

LETTERING ON THE FIGURES.

cu.,	cuticle.
c. isl.,	cell-islet.
ect.,	ectoderm.
ect. m.,	ectodermal muscle.
enc. sin.,	encircling sinus.
end.,	endoderm.
end. sph. m.,	endodermal sphincter muscle.
gl. c.,	gland-cells.
incr.,	incrustations.
mes.,	mesoglœa.
mes. fil.,	mesenterial filaments.
mest.,	mesentery.
mth.,	mouth.
nem.,	nematocyst.
ner. l.,	nerve layer.
nuc.,	nuclei.
mes. sph. m.,	mesoglœal sphincter muscle.
mr. m.,	macrocnemic mesentery.
œs.,	œsophagus.
p. b. m.,	parieto-basilar muscle.
p. gr.,	pigment granules.
r. ect.,	reflected ectoderm.
t_1,	outer row of tentacles.
t_2,	inner row of tentacles.
s. d.,	sulcar directive mesenteries.
sp.,	spermaria.

Figure.

1. *Epizoanthus minutus*, n. sp. (p. 369). Vertical section through a portion of the column-wall, showing the sphincter muscle, tentacles (cut obliquely), disc, œsophageal wall, and mesentery, × 50. Polyp extended.
2. *Epizoanthus minutus*, n. sp. (p. 369). Transverse section through a portion of the column-wall and the grooved part of the disc in a partially extended polyp, showing the united bases of the tentacles, × 50.
3. *Epizoanthus minutus*, n. sp. (p. 369). Transverse section through a portion of a tentacle, × 200.
4. *Epizoanthus minutus*, n. sp. (p. 369). Transverse section through a portion of the column-wall, and the mesenteries below the œsophagus, × 50.
5. *Parazoanthus Swiftii* (Duch. and Michl.), (p. 372). Vertical section through a portion of the column-wall, base, and cœnenchyme, × 50.
6. *Parazoanthus Swiftii* (Duch. and Michl.), (p. 372). Transverse section through a portion of the column-wall and a fertile mesentery, × 280.

Plate XX.

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[April, 1898.]

THE SCIENTIFIC TRANSACTIONS OF THE ROYAL DUBLIN SOCIETY.

VOLUME VI.—(SERIES II.)

XV.

RADIATION PHENOMENA IN A STRONG MAGNETIC FIELD.

By THOMAS PRESTON, M.A., F.R.U.I.

(Plate XXI.)

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XV.

RADIATION PHENOMENA IN A STRONG MAGNETIC FIELD.

By THOMAS PRESTON, M.A., F.R.U.I.

(Plate XXI.)

[Read December 22, 1897.]

In March, 1897, the Philosophical Magazine contained a communication by Dr. Zeeman, in which he announced the important discovery that when a source of light is placed in a strong magnetic field, the spectral lines become sensibly modified in appearance. The modification then described by Dr. Zeeman, as recorded by eye-observations, consisted essentially in a broadening of the bright lines of the spectrum. Fortunately, the electromagnetic theory has been so far advanced as to deal with this phenomenon, and Prof. Lorenz at once pointed out that each broadened line should exhibit certain peculiarities of structure, namely, that it should really consist of three lines, superposed or separated, according to the strength of the magnetic field; that is, when the source of light is placed in the magnetic field and viewed across the lines of force, each spectral line should be divided into three, or become a triplet, and further, that each line of such a triplet should be plane polarised, the outside lines being polarised in one plane, while the middle line is polarised in a perpendicular plane.

This polarisation was very easily tested, and the anticipations of theory were found to be in exact accordance with the experimental facts. Further, if the effect of the magnetic field is to resolve the lines of the spectrum in the manner here indicated, but still if the strength of the field is not sufficient to effect sufficiently wide resolution to completely separate the components of the triplet, but leaves them overlapping, so that, when viewed, the modified line does not appear as a triplet, but merely as a broadened line, then the constitution of this broadened line may be studied, to some extent, by means of the polarisation of its constituents. For, if a Nicol's prism be placed in the path of the light, it will, in one position, cut off the central constituent, and leave the middle of the line dark or weaker; while in the rectangular position it will cut off the two side lines, and so reduce the width of the modified line. If the resolution, however, has been sufficient to separate the inner edges of the two side lines by a distance greater than the width of the unmodified line than the modified line, according to theory, should appear to the eye as a distinct triplet, each component of which can be studied separately, but if the separation of the inner edges is less than this amount, but greater than zero, then, when the nicol is placed in position, so as to remove the middle compact, the side lines should be separated by a dark space, having the appearance of a doublet, and thus the existence of the triplet constitution of the modified line might be inferred, even though a field could not be obtained strong enough to resolve the line into a completely separated triplet.

Although it is highly satisfactory to obtain evidence, in this way, of the existence of the triple constitution of the modified lines, it, no doubt, is still more eminently satisfactory to urge the resolution to such a pitch that the components shall be completely separated, and the triplet, if such exists, shall stand out as three distinctly separated lines. The character of each component can then be separately studied, and the laws which govern the resolution can be investigated under conditions which lend themselves with facility to accurate measurement. Further, the differences, if any, in the effects produced by the same magnetic field on the various spectral lines of the same substance, or different substances, can be examined in detail; and further information may be gleaned concerning the mutual relations of the spectral lines, in groups and series, and possibly a fuller insight may be acquired concerning those vibrations associated with matter which give rise to the spectrum itself.

With the object of ultimately investigating these relations and with the immediate object of first verifying Dr. Zeeman's experiments, I availed myself of the opportunity courteously afforded me of using the concave grating mounted in the Physical Laboratory of the Royal University of Ireland. This instrument has a radius of 21·5 feet, and is ruled with about 14,438 lines to the inch. The electro-magnet which I at first employed was kindly lent me by Prof. Barrett, of the Royal College of Science, Dublin: it is of the usual U-shaped type, and of very moderate power, having a core of about 2 inches diameter of soft iron.

For the information of those who may wish to repeat these experiments, I may mention here that, at first, I had very great difficulty in obtaining any effect whatsoever. Indeed, it seemed as if the effect did not exist, for the spectral lines remained, as far as I could determine, absolutely unaltered when the magnet was excited. Often, indeed, the lines seemed to be altered in breadth or brightness when the field was excited, but the effect was so indefinite that it might easily have been attributed to the observer's imagination.

At length, by pushing the pole pieces of the magnet quite close together, so as to leave only a small space for a very small spark between them, I was able to so increase the strength of the magnetic field around the source of light that I not only obtained pronounced broadening, but, on further careful adjustment, I was able to completely separate the components in the case of certain lines and photograph the modified line as a distinct triplet.

Typical of this class of lines are the lines 4678 and 4680 of cadmium and zinc. These lines are in the violet end of the spectrum, near the blue, and are not to be confounded (as to the effect *exhibited*) with the blue cadmium line of 4800, or the D lines of sodium, which appear to be the lines investigated by Zeeman and other observers. As to the distinction between the classes of effect as exhibited by the *appearance* of the modified lines, I shall speak more fully in the sequel; at present it is sufficient to state that, although some become resolved into distinct triplets, others photograph as doublets (the light being viewed across the lines of force), or weak-middled, greatly broadened lines, having the appearance of quartets; while, on the other hand, many lines appear to be simply broadened in the same magnetic field, and others seem to be scarcely influenced in the same magnetic field.

It is clear, therefore, that the magnetic effect depends not so much on the wave-length of the spectral line as on some hidden quality which we may refer to as the character of the line; for lines of nearly the same wave-length, even of the same substance, show effects which differ remarkably in magnitude and character. Such laws, therefore, as that the broadening of the spectral lines is proportional to the wave-length, or to the square of the wave-length are shown to be utterly untenable, unless, perhaps, it might be possible to group the spectral lines of each substance into sets, so that some law of wave-length might apply to the lines of each set.

For the purpose of investigating this important point, more especially as certain limited groupings of the spectral lines have already been made, it became clear that a stronger magnetic field would be a matter of the highest importance. I consequently determined to have an electro-magnet built according to a special design, with the hope of producing an intense magnetic field in the region occupied by the source of light. While this instrument is being constructed I have been able to obtain the use of a large U-shaped electro-magnet, which gives me a considerably stronger field than that which I at first employed. For the use of this instrument I am indebted to the great kindness of the Right Rev. Monsignor Molloy.

With it I have been able to work up the magnetic field to such a strength (by bringing the pole-pieces very close together and using a very small spark) that the photographs display the triplets of the zinc and cadmium lines 4680 and

4678, distinctly separated to the *naked eye* on the photographic plate. The distance between the side lines of the triplet is sensibly the same for both these lines and measures, 0·56 mm. Taking the magnetic field at about 25,000 cgs. units, we may state therefore in round numbers that a field of 20,000 cgs. units will originate a difference of wave-length of one Angström unit between the side lines of the triplets 4680 of zinc or 4678 of cadmium. In other words, the line 4680, say, is converted by a magnetic field of 20,000 cgs. units into three lines of wave-lengths, 4680·5, 4680, and 4679·5 respectively.

Using the formula given by Dr. Larmor* for the change of frequency produced by the magnetic field we have

$$n_1 - n_2 = \frac{2\pi eH}{Mv^2},$$

where n_1 and n_2 are the frequencies of the side lines of the triplet, viz. the frequencies of the two lines induced by the magnetic field, and v is the velocity of light. Hence for the difference of wave-length $\delta\lambda$, we have

$$\frac{\delta\lambda}{\lambda^2} = \frac{2\pi eH}{Mv^3},$$

which, for the wave-length 4680 (of zinc) gives in round numbers

$$\frac{e}{M} = 10^6 v^2$$

as the approximate value of the ratio of e to M in this case; or in electro-magnetic units, the ratio is about one to a million for this particular line.

With such a resolution as this in the case of these lines, which belong to what we may term the normal triplet type, it resulted that, as one should expect, many of the lines which were previously unresolved became separated, and, further, the constitution of those which did not show as normal triplets was rendered much clearer. Thus, if we refer to the photographs illustrating this Paper, we see that while the normal triplet 4680, say, consists of three distinctly separated lines, of which the middle one is the most intense, yet the neighbouring lines, such as 4800 (the blue cadmium line observed by Zeeman and others) do not appear as triplets of this type. On the contrary, nearly all the light is sometimes concentrated in the two outside lines, leaving a weak middle, which exhibits the appearance, not of a single middle line, but of two weak middle lines, so that the resultant appearance of the modified line is a quartet, in which the two outside lines generally are much stronger than the two inside lines. Further, in some

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* Dr. J. Larmor, *Phil. Mag.* vol. XLIV., p. 503, Dec. 1897.

cases the two inside lines are absent altogether, so that we are presented with what appears to be a doublet instead of a triplet (the light being still viewed across the lines of force).

This, at first sight, extraordinary modification, or variation, of the expected triplet may be accounted for in more than one way. Thus the central line of the triplet might be almost wholly, or partially, obliterated by absorption in the outer layers of the colder vapour surrounding the source of light. That is, the basis of this modification of the triplet may be what is known as reversal. If the central line is completely absorbed, we are left with a doublet; and if the middle part only of the central line is absorbed, we are left with two strong outside lines enclosing two weak inside lines—that is, a quartet with a weak middle, such as the line 4800 appears. Further, since the absorbing vapour is itself in a strong magnetic field, it is possible that the outside lines of the triplets may also be reversed; that is, each line may be replaced by two bright lines, separated by a dark space. The appearance then presented, when each line of the triplet is reversed, should be, not three, but six bright lines separated by dark spaces. If, however, the central line of the triplet should be completely absorbed, while the outside lines are reversed, we are presented with two pairs of bright lines instead of a triplet.

Now, in carefully examining this phenomenon, I have repeatedly observed all the modifications just mentioned, that is to say, while some lines are resolved into sharp distinct triplets, having the middle line the brightest, others in the same field are resolved into what appear to be quartets and sextets. It is interesting to notice that the two D lines of sodium, and the blue line 4800 of cadmium do not belong to the class which show as triplets. In fact, the blue cadmium line belongs to the weak-middled quartet class, while one of the D lines (D_2) shows as a sextet of fine bright lines, *i.e.* four sharp and equally intense lines enclosed by two somewhat less sharp on the outside. On the other hand, the other D line (D_1) shows as a quartet, not of the weak middled class, such as 4800 of cadmium, but of the doublet type, that is, of the type which would result from the complete absorption of the central line combined with the sharp reversal of each of the side lines.

Thus the modifications introduced by absorption in the vapour of the outside layers of the source of light sufficiently explain the alteration in the number of the component lines which make up the image of the modified line as viewed in the eye-piece, or recorded on the photographic plate. The *appearance* of the image however, is not that which are ordinarily associates with reversal, for, in a reversed line, there is generally a grading of the light towards the outside and a sudden fall of intensity, or sharp edge, on the borders of the inside dark line or reversal. This characteristic appearance is absent in all the cases cited above, and for this reason I have spent a considerable amount of time in investigating whether the appearances are really due to reversal or not.* Up to the present, however, I have not been able to obtain any decisive information on this important point; but on the whole I am inclined to the opinion that all the variations of the normal triplet appearance which I have observed may be sufficiently accounted for by absorption. This point however, I hope to return to, as soon as I obtain a stronger magnetic field, and for the present it is best to regard it as not absolutely decided.

Indeed, if we consider this question from a theoretical standpoint, there seems to be no good reason why we should not have doublets as well as triplets, or triplets with weak middles, or other modifications, when the source of light is viewed across the lines of force. For, if the influence of the magnetic field on the vibrating systems (be they what they may), be such as to set the plane of any one vibration at right angles to the lines of force, then the component of this vibration in the direction of the lines of force will vanish, that is, the constituent of the unmodified period which gives rise to the central line of the triplet, will vanish, and we shall be left with a doublet; or on the other hand, if the vibration became directed wholly along the lines of force, the period would remain unaltered, and the line should be quite unaffected by the magnetic field.

In fact, in order that a line should be converted into a normal triplet having the middle line equal in intensity to the two side lines combined, it is necessary to assume that the freedom of vibration is the same in every direction in the system. But if this be not the case, then modifications of the type of normal triplet will occur and should be searched for. If these are proved to exist, our knowledge of the difference in character of the different spectral lines will be considerably increased; but if not, and if all the observed modifications are proved to be due to absorption, still the examination of the spectra by means of the influence exerted by a magnetic field retains a high value; for, by it, we may be led to the grouping of the spectral lines in such a way that the general laws of their recurrence may be discovered and hence inferences may be made as to the nature of the events taking place in the vibrating systems which give rise to them.

Another cause which may be operative in producing deviations from the normal triplet produced by the magnetic field may lie in the constitution of the line itself Thus, if a spectral line be not a simple line, but a close doublet,† then each constituent will be converted into a triplet by the magnetic field; and if the corresponding lines of these triplets, which overlap, differ in phase by the same or different amounts, decided modifications will be introduced into the appearance of the

---

* It should be remarked that in none of these cases does the line exhibit reversal when the magnetic field is unexcited.

† Michelson has already found that some of the spectral lines possess complexity of this nature: A. A. Michelson, *Phil. Mag.* vol. xxxiv., p. 280, 1892.

normal triplet. For example, if the corresponding lines differ in phase at their centres by half a period, then a sextet would result; and if the middle lines only differ in phase, a doublet or a weak-middled quartet would result. In fact, all the appearances observed so far might result in this manner, and, if so, additional light will be thrown on the structure of the spectral lines. It is just possible, however, that the complexity of structure observed by Michelson may itself be due to intermittent reversal, that is, absorption.

EXPLANATION OF PLATE XXI.

In the accompanying Plate (XXI.), fig. 1 shows the effect produced on the violet line of cadmium 4678. At the top, *a*, we have the line photographed with the magnet unexcited, that is, in the free field. Underneath this, at *b*, the same line is photographed with the magnet excited, but the field is not strong enough to resolve it into its three constituents. It accordingly appears to be merely broadened by the magnetic field. A Nicol's prism was then introduced into the path of the light and the line photographed in the same magnetic field, with the result shown at *c*, where the middle is seen to be removed from the affected line, so that it appears as a doublet. The nicol was then turned through a right angle and the line again photographed in the same field. The result is shown at *d*, which proves that the sides of the broadened line have been cut off, while the middle has been allowed to pass. This agrees with the supposition that the magnetic field resolves the line into a triplet, but it does not prove it.

The further resolution necessary to prove this point is shown in figs. 2 and 3. In fig. 2 a photograph of the zinc lines 4811, 4722, and 4680 is shown, and it will be observed that 4680 shows as a pure triplet, while the others do not. Fig. 3 is a photograph in a still stronger field taken from a spark passing between two electrodes, one of cadmium and one of zinc, so that the lines of cadmium and zinc are obtained simultaneously under precisely the same circumstances. It will be seen that the lines most affected are 4678 of cadmium and 4680 of zinc, and these both show as pure triplets, while the lines 4722 and 4800 show as quartets.

Fig. 1

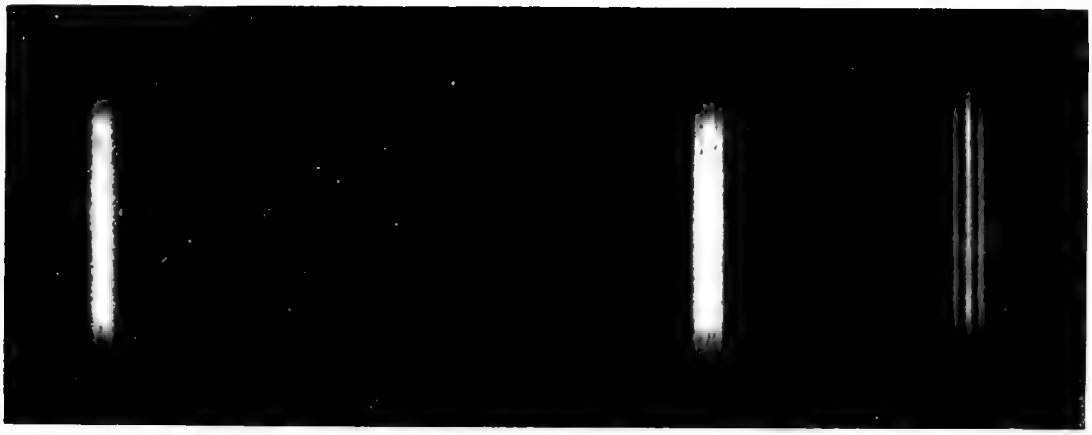

Fig. 2

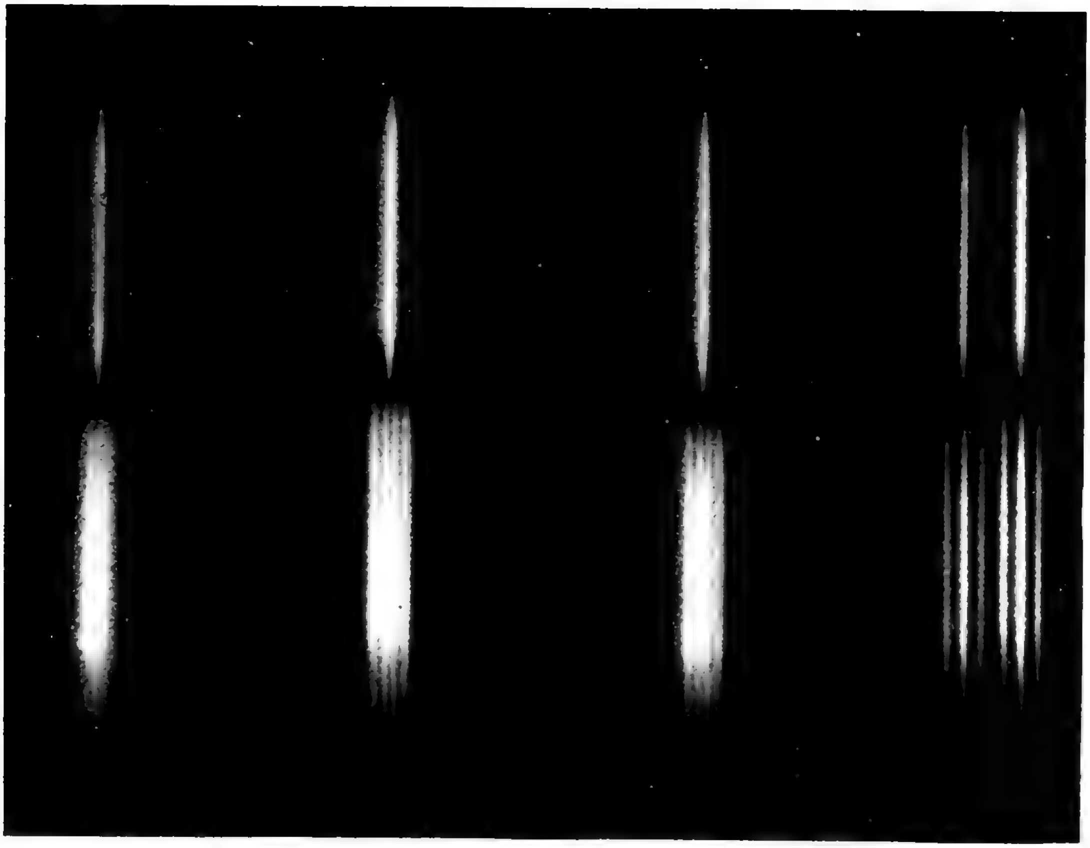

Fig. 3

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THE
SCIENTIFIC TRANSACTIONS
OF THE
ROYAL DUBLIN SOCIETY.

VOLUME VI.—(SERIES II.)

XVI.

THE ACTINIARIA OF TORRES STRAITS.

BY ALFRED C. HADDON, M.A., D.Sc.,
Professor of Zoology, Royal College of Science, Dublin.

(PLATES XXII. TO XXXII.)

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By ALFRED C. HADDON, M.A., D.Sc.,
Professor of Zoology, Royal College of Science, Dublin.

(Plates XXII. to XXXII.)

[Read November 17, 1897.]

The following account of the Actiniaria which have been observed in the Torres Straits is based mainly on the collections made by myself in 1888–9, and supplemented by descriptions published by Saville-Kent in his magnificently illustrated books "The Great Barrier Reef of Australia," and "The Naturalist in Australia."

A large proportion of the species have been anatomically studied by Miss Alice M. Shackleton and myself, and I would like to take this opportunity of thanking her for her share in the following memoir. In our Paper, entitled "Description of some New Species of Actiniaria from Torres Straits," and published in the *Proceedings* of this Society in 1893, we described twenty-four new species in addition to the ten new species of Zoantheæ previously published by us in the *Transactions* of this Society (vol iv., ser. II., 1891). One form, *Actinia citrina*, was carefully studied by Dr. A. Francis Dixon (now Professor of Anatomy at University College, Cardiff, S. Wales). I would also like to tender my thanks to my friends Mr. J. E. Duerden (Curator of the Museum of the Institute of Jamaica, Kingston, Jamaica, and formerly of this College); Dr. O. Carlgren of Stockholm; Prof. J. Playfair McMurrich of Michigan, and other colleagues.

In the present communication, fifty-five species are recorded from Torres Straits, of which five are now described for the first time; thirty-four were first described by Miss Shackleton and myself; eight by Saville-Kent; and the rest are species which occur elsewhere, and have been described by various zoologists. It is, however, probable that various other species will be recorded from this district in the future.

It will be seen that most of the groups of Actiniaria are represented, the most noticeable gaps being the Edwardsiæ, Protactiniæ, Ilyanthidæ, Paractidæ, Dendromelidæ, and of the Phyllactidæ only one species is recorded. With regard to these, it is probable that certain members of most of the deficient groups will be eventually found here. No important tropical family is absent, and indeed very few tropical genera are unrecorded.

Finally, I should offer an apology for the delay in the appearance of this memoir. My attention has been increasingly drawn towards Anthropology, and I have allowed other interests to take precedence of this too long delayed Report.

A word of thanks and of praise is due to my friend Mr. Wilson, the clever scientific artist at Cambridge, who has translated my rough sketches into very excellent representations of the living forms—whatever defects may be subsequently shown to occur in them must solely be credited to me.

I have made a few allusions to genera which are not recorded from Torres Straits, partly to render this Paper more complete, and partly because I am starting once more on my travels, and it will be some years before I can return to my Actiniarian studies. I have not given the full synonymy in most cases, as that will be found in the memoirs of Andres, McMurrich, Carlgren, &c., to which I have so often referred.

Systematic List of the Genera referred to in this Paper.

ACTINIARIA.

Tribe I.—EDWARDSIÆ, Hertw.

Family.—Edwardsiidæ, Andr.

Edwardsia, Quatr.
Edwardsiella, Andr.
Edwardsioides, Danl.
Milne-Edwardsia, Carlgr.

Tribe II.—CERIANTHEÆ, Hertw.

Family—Cerianthidæ, M. Edw. & H.

Cerianthus, D. Ch.
Saccanthus, M. Edw.
Bathyanthus, Andr.

Tribe III.—ZOANTHEÆ, Hertw.

Family.—Zoanthidæ, Dana.

Sub-family—Brachycneminæ, H. & S.

Zoanthus, Lam.
Isaurus, Gray.
Gemmaria, D. & M.
Palythoa, Lamx.
Sphenopus, Steenstr.

Sub-family—Macrocneminæ, H. & S.

Parazoanthus, H. & S.
Gerardia, Lac.-Duth.
Epizoanthus, Gray.

Tribe IV.—PROTACTINIÆ, M^{c}M. (Protantheæ, Carlgr.).

Family—Gonactiniidæ, Carlgr.

Gonactinia, Sars.
Oractis, M^{c}M.
Protanthea, Carlgr.
? Scytophorus, Hertw.
? Halcurias, M^{c}M.

Tribe V.—HEXACTINIÆ, Hertw.

Order I.—Actiniinæ, M. Edw.

Family 1.—Ilyanthidæ, Gosse.

Sub-family.—Halcampinæ, Kwietn. (Halcampomorphinæ, Carlgr.).

Halcampa, Gosse, p.p.
Peachia, Gosse (Siphonactinia, D. & K.).
Ilyanthus, Forbes.
? Eloactis, Andr.

Sub-family.—Halianthinæ, Kwietn. (Halcampinæ, Carlgr.).

Halianthella, Kwietn.
Halcampa, p.p.
? Andvakia, Danl.
? Halcurias, M^{c}M.

Family 2.—Actiniidæ, Gosse (Antheadæ, Hertw.).

Actinia, Browne.
Anemonia, Risso (? Gyrostoma, Kwietn.).
Condylactis, D. & M.
Antheopsis, Sim.
Actinioides, H. & S.
Bolocera, Gosse (Liponema, Hertw.; ? Sideractis, Danl.).
Polystomidium, Hertw.
Macrodactyla, n. g.
Myonanthus, M^{c}M.
Antheomorphe, Hertw.

Family 3.—Aliciidæ, Duerd.

Alicia, Johns.
Cystiactis, M. Edw.
Thaumactis, Fowl.
Bunodeopsis, Andr.
? Phymactis, M. Edw.

Family 4.—Phyllactidæ, Andr.

Phyllactis, M. Edw.
Oulactis, M. Edw. & H.
Cradactis, M^{c}M.
Diplactis, M^{c}M.
Hoplophoria, Wils. (? Viatrix, D. & M.).
Asteractis, Verr.
? Phyllodiscus, Kwietn.
? Triactis, Klunz.

Family 5.—Dendromelidæ, McM.

Ophiodiscus, Hertw.
Lebrunea, D. & M.

Family 6.—Bunodidæ, Gosse.

Bunodes, Gosse.
Aulactinia, Verr.
Ixalactis, n. g.
? Heteractis, M. Edw.
Leiotealia, Hertw.
Urticina, Ehr. (Tealia, Gosse).
Gyractis, Bov.

Family 7.—Paractidæ, Hertw.

Paractis, M. Edw.
Paranthus, Andr.
Anthosactis, Danl.
Stomphia, Gosse.
Dysactis, M. Edw.
? Ophiodiscus, Hertw.
Tealidium, Hertw.
Antholoba, Hertw.
Actinernus, Verr. (Polysiphonia, Hertw.).
Actinostola, Verr.
Pycnanthus, McM.
Cymbactis, McM.
Kadosactis, Danl.
Kyathactis, Danl.

Family 8.—Sagartiidæ, Gosse.

Sub-family.—Aiptasiinæ, Sim.

Aiptasia, Gosse.

Sub-family.—Sagartiinæ, Verr.

Sagartia, Gosse.
Cylista, Gosse.
Gephyra, Koch.
Cereus, Oken (Heliactis, Thomps.).
Nemactis, M. Edw.

Sub-family.—Phelliinæ, Verr.

Phellia, Gosse.
? Octophellia, Andr.

Sub-family.—Metridiinæ, Carlgr.

Metridium, Oken (Actinoloba, Blainv.).
Mitactis, H. & D.
Adamsia, Forbes.
Calliactis, Verr.
Stelidiactis, Danl.

Sub-family.—CHONDRACTINIINÆ, Hadd.

Actinauge, Verr.
Hormathia, Gosse (Chondractinia, Lütk., Chitonactis, Fisch.).
Chitonanthus, M^{c}M.
Paraphellia, Hadd.
Phelliactis, Sim.
? Stephanactis, Hertw.
? Amphianthus, Hertw.
? Ammonactis, Verr.

Family 9.—MINYADIDÆ, Andr.

Minyas, Cuv.
Stichophora, Brandt.
Plotactis, M. Edw.
Nautactis, M. Edw.
Oceanactis, Mos.

Order II.—STICHODACTYLINÆ, Andr.

Family 1.—CORALLIMORPHIDÆ, Hertw. (Corynactidæ, Andr.).

Corallimorphus, Mos.
Corynactis, Allm.
? Capnea, Forbes.
? Aureliania, Gosse.

Family 2.—DISCOSOMIDÆ, Klunz.

Discosomoides, n. g.
Discosoma, Leuck.
Radianthus, Kwietn.
Stoichactis, n. g.

Family 3.—RHODACTIDÆ, Andr.

Rhodactis, M. Edw. & H.
Actinotryx, D. & M. (Platyzoanthus, S.-Kent).
Ricordea, D. & M. (Homactis, Verr.; ? Phialactis, Fowl.).
Heteranthus, Klunz.

Family 4.—THALASSIANTHIDÆ, Andr.

Cryptodendrum, Klunz.
Heterodactyla, Ehr.
Actineria, Blainv.
Thalassianthus, Leuck.
Sarcophianthus, Less.
Amphiactis, Verr.

Family 5.—ACTINODENDRIDÆ, n. f.

Actinodendron, Blainv.
Megalactis, Ehr.
Acremodactyla, Kwietn.
Actinostephanus, Kwietn.

Family 6.—PHYMANTHIDÆ, Andr.

Phymanthus, M. Edw.
Thelaceros, Mitch.

[*Incert. sedis*: Physobrachia, S.-Kent.]

LIST OF SPECIES OF ACTINIARIA FROM TORRES STRAITS.*

CERIANTHEÆ, . . *Cerianthus nobilis*, H. & S.

ZOANTHEÆ, . . . *Zoanthus Coppingeri*, H. & S. ; *Z. Jukesii*, H. & S.; *Z. Macgillivrayi*, H. & S.; *Z. Australiæ*, (S.–Kent); *Isaurus asymmetricus*, H. & S. ; *Gemmaria Macmurrichi*, H. & S. ; *G. Mutuki*, H. & S. ; *Palythoa Howesii*, H. & S.; *P. Kochii*, H. & S. ; *P. cæsia*, Dana (?) ; *Sphenopus arenaceus*, Hertw. ; *Parazoanthus dichroicus*, H. & S.; *P. Douglasi*, H. &. S.

HEXACTINIÆ—I. ACTINIIÆ:—

Actiniidæ: *Actinia citrina*, (H. & S.) ; *Anemonia Ramsayi*, (H. & S.); *A. Kwoiam*, H. & S.; *Actinioides Dixoniana*, H. & S.; *A. Papuensis*, n. sp.; *A. Sesere*, H. & S.; *Macrodactyla aspera*, (H. & S.).

Aliciidæ: *Alicia rhadina*, H. & S. ; *Bunodeopsis Australis*, n. sp.

Phyllactidæ: *Hoplophoria cincta*, (H. & S.).

Bunodidæ: *Aulactinia Gelam*, (H. & S.); *Ixalactis simplex*, (H. & S.).

Sagartiidæ: *Sagartia Milmani*, H. & S.: *Sagartia plebeia*, n. sp.; *Phellia vermiformis*, n. sp.; *P. sipunculoides*, H. & S.; *P. Devisi*, H. & S.; *Calliactis Miriam*, (H. & S.); *Paraphellia Hunti*, H. & S.; *P. lineata*, H. & S.

Minyadidæ: *Stichophora torpedo*, (Bell).

,, II. STICHODACTYLINÆ:—

Corallimorphidæ: *Corynactis hoplites*, H. & S.

Discosomidæ: *Radianthus macrodactylus*, (H. & S.); *R. Malu*, (H. & S.); *Stoichactis Kenti*, (H. & S.); *S. Haddoni*, (S.-Kent): [? *Discosoma nummiforme*, Leuck; ? *D. rubraoris*, S.-Kent].

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* The form described by Saville-Kent as *Physobrachia Douglasi* (cf. p. 498), is so imperfectly described that I do not know where to place it. It may prove not to be an Actiniarian, but a Madreporarian coral. Kwietniewski has described *Gyrostoma Hertwigi*, from Thursday Island, as a type of a new family, and even of a new tribe, the Isohexactiniæ. I have stated on p. 420 that I believe this species to be a variety of *Anemonia Ramsayi* (H. & S.).

HEXACTINIÆ.—II. STICHODACTYLINÆ—*continued.*

Rhodactidæ: *Rhodactis Howesii*, S.-Kent; *Actinotryx bryoides*, (H. & S.); *A. mussoides*, (S.-Kent).

Thalassianthidæ: *Cryptodendrum adhæsivum*, Klunz; *Heterodactyla Hemprichii*, Ehr.; *H. hypnoides*, S.-Kent; *Actineria dendrophora*, H. & S.

Actinodendridæ: *Actinodendron plumosum*, n. sp.; *A. glomeratum*, n. sp.; *Megalactis Griffithsi*, S.-Kent.

Phymanthidæ: *Phymanthus muscosus*, H. & S

ACTINIARIA, or MALACODERMATA.

Cœlenterata, with various kinds of tentacles arranged in diverse manners, and with usually numerous mesenteries which are mostly in some multiple of six. With no spicular or continuous skeleton. Body moving freely or adhering to supporting substances by means of suction of the pedal disk; rarely firmly fixed; animals usually solitary, rarely forming colonies.

Tribe I.—EDWARDSIÆ, R. Hertwig, 1882.

Free-moving, non-colonial Actiniaria, with eight mesenteries, two pairs of which are directives; the remaining mesenteries are unpaired, and their retractor muscles all face the same way; all the mesenteries are fertile; tentacles simple, usually more numerous than the mesenteries.

Family.—EDWARDSIIDÆ, Andres, 1880.

This family has recently been studied by Carlgren, and I have no new observations to record. I believe that my Swedish friend has now discarded his new family of Milne-Edwardsiidæ, but has two new genera to add to those given above.

No specimen of this tribe is recorded from Torres Straits.

Edwardsia, Quatr., 1842; Edwardsiella, Andr., 1884; Edwardsioides, Danl., 1890; Milne-Edwardsia, Carlgr., 1893.

Tribe II.—CERIANTHEÆ, R. Hertwig, 1882.

Actiniaria, with numerous pairs of mesenteries so arranged that each mesentery of the one side of the directive mesenteries forms a pair with the corresponding one on the other side. A single anterior (or dorsal) œsophageal groove. The mesenteries at the anterior end of the polyp (on the dorsal side) are the longest, gradually decreasing in size going backwards (ventrally); the two mesenteries attached to the bottom of the œsophageal groove (the directive mesenteries) are remarkably small, and are distinguished in this way from the other anterior (dorsal) mesenteries. Body-wall with strongly-developed ganglionic and longitudinal muscular layers.

Family.—CERIANTHIDÆ, M. Edw. et Haime, 1852.

Ceriantheæ with a double corona of tentacles, marginal principal tentacles and circum-oral accessory tentacles; posterior end of body rounded; with feeble transverse mesenterial muscles which are turned towards the directive mesenteries, the longitudinal muscles being turned away from them; no sphincter.

Cerianthus, D. Ch.; Saccanthus, M. Edw.; Bathyanthus, Andr.

CERIANTHUS, Delle Chiaje, 1832.

Cerianthidæ with an aboral pore; with a sheath consisting of mud, sandgrains, and nematocysts, in which the posterior (proximal) end of the polyp lies as if in a case.

Cerianthus nobilis, H. & S.

Cerianthus nobilis, Hadd. and Shackl., 1893, Proc. R. D. S. VIII., p. 118; Saville-Kent, 1893; "The Great Barrier Reef of Australia," p 151, chromo pl. iii., fig. 7.

Form.—Body of great size, presence of a terminal pore not determined. Marginal tentacles long, tapering, in three cycles from about 160 to 170 in number, about 79 tentacles in the outermost cycle. Oral tentacles very numerous, much smaller than the marginal tentacles.

Tube, thick, rugose, gelatinous.

Colour.—Upper portion of body rich, deep brown; lower portion, creamy brown, with irregularly arranged, fine, longitudinal, brown lines, and one broad pale band. Marginal tentacles, deep flesh colour (No. 31 of Broca's skin colours), with a broad or narrow line down each side. Disk, with radial brown lines, one radius being pale with two dark brown marks at the base of the corresponding tentacles. Oral tentacles more yellow than the marginal tentacles; "inner tentacles usually pearl-grey; outer series most commonly pale lemon-yellow, varying to a dark red-brown or nearly black."—S.-K.

Size.—Length of body probably about 300 mm. ($11\frac{3}{4}$ in.); of the preserved specimen 105 mm. Diameter of living body about 26 mm. (1 in.); of the preserved specimen 19 mm. Length of marginal tentacles about 80 mm. ($3\frac{1}{4}$ in.). Length of tube about 345 mm.; average diameter of tube in middle 36 mm.

Locality.—Partially embedded in the mud on the fringing reef of Thursday Island and Warrior Island, Torres Straits, and at Port Darwin.

Saville-Kent found numerous young ones, about an inch in length, "enclosed, in some numbers, in the substance of the felt-like sheath of the parent polyps" in some specimens collected at Warrior Island.

Although no pore is visible in the preserved specimen, I do not hesitate to allocate this fine species to the genus Cerianthus, the great state of contraction of the more flaccid aboral end of the body would very well make it difficult to definitely assert the absence of a pore in spirit specimens.

The single example was not sufficiently well preserved to enable me to say much as regards the histology of this species. Thanks to the labours of Haime, von Heider, the brothers Hertwig, Jourdan, Danielssen, McMurrich, and Carlgren, we have a very good knowledge of the minute anatomy of several members of the genus; McMurrich ("Contributions on the Morphology of the Actinozoa: I. The Structure of *Cerianthus Americanus*," Journal of Morphology, IV. 1890: p. 131) gives a brief summary of the literature of the anatomy of the genus, and compares his investigations with those of other authors. More recently (1893, p. 201) he redefines the Tribe of Ceriantheæ, and describes a new species (*C. vas*) in which he could not discover any tentacles. Carlgren (1893, p. 239; 1894, p. 119) gives an account of *C. Lloydii*, and discusses the morphology of the group. I have adopted his definitions which are modified from those of Hertwig.

It is possible that this species is nearly allied to *C. orientalis*, Ver., from Hongkong (Verrill, Proc. Essex Instit. iv. 1865, p. 151; Ann. Mag. Nat. Hist. xvi. 1865, p. 196; Andres, 1884, Le Attinie, p. 347).

Tribe III.—ZOANTHEÆ, R. Hertwig, 1882.

Actiniaria with numerous perfect and imperfect mesenteries, and two pairs of directive mesenteries, of which the sulcar are perfect, and the sulcular imperfect. A pair of mesenteries occur on each side of the sulcular directives, of which the sulcular moiety is perfect, and the sulcar imperfect; a second similar pair occurs in one group (Brachycneminæ); or the second pair may be composed of two perfect mesenteries (Macrocneminæ). In the remaining pairs of mesenteries, in both groups, this order is reversed, so that the perfect mesentery is sulcar, and the imperfect is sulcular. The latter series of mesenteries are bilateral as regards the polyp, and arise independently (*i.e.* neither in pairs nor symmetrically on each side) in the exocœl on each side of the sulcar directives, in such a manner that the sulcular are the oldest, and the sulcar the youngest. Only the perfect mesenteries are fertile, or bear mesenterial filaments. A single sulcar, œsophageal groove is present. The mesoglœa of the body-wall is traversed by irregularly branching ectodermal canals, or by scattered groups of cells. The body-wall is usually incrusted with foreign particles. Tentacles simple, marginal. The polyps are fixed and generally grouped in colonies connected by a cœnosarc; the cœlenteron of each polyp communicating with that of the other members of the colony by means of basal endodermal canals.

Family.—ZOANTHIDÆ, Dana, 1846 (with the definition of the Tribe).

Sub-family.—BRACHYCNEMINÆ, Hadd. and Shackl., 1891, p. 626.

Zoantheæ in which the sulcar element of the primitive sulco-lateral pair of mesenteries (cnemes) is imperfect.

ZOANTHUS, Lamarck, 1801.

Brachycnemic Zoantheæ with a double mesoglœal sphincter muscle. The body-wall is unincrusted; the ectoderm is usually discontinuous; a well-developed ectodermal canal system in the mesoglœa. Diœcious or monœcious. Polyps connected by a thin cœnosarc.

Zoanthus Coppingeri, H. & S.

Zoanthus Coppingeri, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 676; Pl. LXI., fig. 1–2; Pl. LXII., fig. 1; Pl. LXIV., fig. 1–4: Saville-Kent, "The Great Barrier Reef of Australia," 1893, p. 152,; chromo pl. iii., fig. 11.

Form.—Body smooth, pyriform when contracted, rather elongated when expanded. Polyps in clusters, the buds springing from the base of the polyps themselves; cœnosarc thin, incrusting.

Colour.—Pinkish below, greenish or bright green above, sometimes entirely pinkish, always with brown streak-like spots; disk burnt-sienna, with darker spots; rim of mouth brown; tentacles grey, with a single row of black spots; there is a black spot between each tentacle, each of which is continued as a black line on the capitulum. (Disk, various shades of green, dull or brilliant; tentacles, rich brown.—S.-K.)

Dimensions.—Height of contracted specimen 15 mm.; diameter of upper portion 5 mm.

Locality.—Fringing reef, Mabuiag.

Zoanthus Jukesii, H. & S.

Zoanthus Jukesii, Hadd. and Shackl., 1891. Trans. R. D. S. (2) IV., p. 678; Pl. LXI., figs. 3–5; Pl. LXII., fig. 2; Pl. LXIII., fig. 1.

Form.—Body short and thick; body-wall smooth and delicate; cœnosarc forming stolons.

Colour.—Body and stolon translucent grey, the endoderm shining through with a brown tint; capitulum pink, with twenty-four dark lines; disk brown, usually with pairs of pale lines (mesenteries) for inner cycle of tentacles; mouth with greenish lip; œsophagus grey; tentacles, inner cycle green with dark marks on the oral aspect, outer cycle opaque pink; all the tentacles with a dark spot at the tip; the base of the tentacles of the outer cycle sometimes tinged with green.

Dimensions.—Height, 7–12 mm.; diameter of disk, 6 mm.

Locality.—Fringing reef, Mer.

Zoanthus Macgillivrayi, H. & S.

Zoanthus Macgillivrayi, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 680, Pl. LXI., fig. 6; Pl. LXII., fig. 3; Pl. LXIII., fig. 2; Pl. LXIV., fig. 5–8.

Form.—Body transversely wrinkled below, smooth and slightly swollen above; with a thick cuticle; disk large; cœnosarc forming a flattened stolon.

Colour.—Yellowish in alcohol.

Dimensions.—Height, 18 mm.; average diameter of column, 3 mm.; diameter of disk, 6·5 mm.

Locality.—Fringing reef, Mabuiag.

Zoanthus Australiæ (Saville-Kent).

Acrozoanthus Australiæ, Saville-Kent, 1893; "The Great Barrier Reef of Australia," p. 154; fig. on p. 153; chromo pl. iii., figs. 4, 4A.
Zoanthus Australiæ, . Haddon, 1895; Proc. R. D. S. VIII. (N.S), p. 346.
Acrozoanthus Australiæ, Saville-Kent, 1897; "The Naturalist in Australia," p. 225; pl. xl.

Form.—Body smooth, about as broad as high, forming somewhat spherical knobs when contracted. The daughter polyps mainly bud from the base of the parent; cœnosarc incrusting.

Colour.—Body dull green, inclining to pinkish, speckled with red-brown; capitulum brilliant emerald-green; oral disk dull orange, spotted with red-brown; tentacles rich chocolate-brown, sometimes somewhat purplish.

Dimensions.—Diameter of expanded corona about 1 inch (25 mm.).

Commensal on a worm tube (said by Saville-Kent to be a species of Nereis; but it may be a species of Eunice. *Cf.* F. Buchanan, "Note on the Worm associated with *Lophohelia prolifera*," Proc. R. D. S. (N. S.), VIII., 1897, p. 432).

Found at low tide round the shores of tropical Australia.

The chief point of interest about this species is the habit it has of association with a tubicolous Annelid. It is evident that the growth of the Zoanthus annoys the worm, owing to its tendency to grow over the terminal orifice. In order to escape, the worm makes a fresh start in another direction, but usually in the same plane, and at a divergent angle of about 60°. Before it has added another inch to its dwelling tube, the polyp has once more overtaken it, and converted its front entrance into a *cul-de-sac.* This process is repeated again and again with great regularity. After about a score or so of obliquely ascending short branches, the polyp appears to be victorious in this zigzag race; for one generally finds that about this stage the tube is uninhabited, and the polyps sit on the closed apertures of the lateral and terminal branches.

Mr. Saville-Kent, when he first described this species, considered that the Zoanthean secreted the tube. In a previous correspondence I argued against this view, and subsequently I wrote a short Paper, in which I pointed out that branched worm-tubes were by no means unknown, although Mr. Saville-Kent had overlooked the fact. I there stated that, anatomically, the Zoanthean belonged to the genus Zoanthus; but that it was a new species. In his recently published book, Mr. Saville-Kent records the discovery of the worm which secretes the tube; and so that point is now settled. He still retains his own generic name for the polyp; but I have no doubt that it must lapse.

The anatomical characters of this species do not call for any special remark. The ectoderm cells are found as in *Z. Jukesii* and *Z. Coppingeri;* the cuticle is very feebly developed. The ectodermal canals in the mesoglœa are numerous and large, and have a tendency to form a disconnected ring near the endoderm. The distal portion of the double sphincter muscle is much more powerful than the proximal, which alone serves to distinguish it from other Zoantheæ of Torres Straits.

ISAURUS, Gray, 1828.

Large brachycnemic Zoantheæ, with a single mesoglœal sphincter muscle. The body-wall is unincrusted; the ectoderm discontinuous; ectodermal and endodermal bays and small canals in the mesoglœa. Monœcious or diœcious. Polyps in small clusters or solitary.

Isaurus asymmetricus, H. & S.

Isaurus asymmetricus, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 684; Pl. LXI., figs. 7–9; Pl. LXII., fig. 4; Pl. LXIII., figs. 4–6; Pl. LXIV., fig. 9.

Form.—Body elongated; upper portion of column with usually four, sometimes more, rather irregular rows of tubercles, arranged in such a manner that there is a longitudinal area free from them; tubercles rarely absent; the smooth side is somewhat shorter than the tuberculated, so that the body bends over to the former. The contracted capitulum exhibits radiating furrows. The polyps grow either singly or in small clusters.

Colour.—Whitish below, passing into brownish above; the darker portion variously mottled with cream, or greenish cream, and occasionally diversified with darker spots; tubercles somewhat pinkish.

Dimensions.—Average size of retracted specimens, 45 mm. in height; greatest diameter, 7 mm.

Locality.—On reefs and between channels.

GEMMARIA, Duch. and Mich., 1860.

Brachycnemic Zoantheæ, with mesoglœal sphincter muscle; solitary, or connected by cœnosarc; the body-wall incrusted with grains of sand and spicules; the ectoderm usually discontinuous, but may be continuous. Lacunæ and cell-islets are found in mesoglœa. Diœcious.

Gemmaria Macmurrichi, H. & S.

Gemmaria Macmurrichi, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 688; Pl. LXI., fig. 11; Pl. LXIII., fig. 7.

Form.—Erect, rigid; upper portion of contracted specimen with minute radiating corrugations.

Colour.—Sandy.

Dimensions.—Height, 13 mm. (in spirit); diameter, 2–3·5 mm.

Locality.—Channel between Murray Islands, 20 faths.

Ectoderm discontinuous, no zooxanthellæ.

Gemmaria Mutuki, H. & S.

Gemmaria Mutuki, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 689; Pl. LXI., fig. 10; fig. 1, p. 690.

Form.—Nearly cylindrical; upper portion of retracted specimens with a large number (24–30) of fine radial ridges, which are continued some way down the column; lower portion of column wrinkled in spirit specimens. Basal gemmation occurs.

Colour.—Greyish white in spirit.

Dimensions (in spirit).—Height, 10–12 mm.; average diameter, 4·5 mm.

Locality.—Mabuiag.

Ectoderm continuous, zooxanthellæ present.

PALYTHOA, Lamouroux, 1816.

Brachycnemic Zoantheæ with a single mesoglœal sphincter muscle. The body wall is densely incrusted. The ectoderm is continuous (?); the mesoglœa contains numerous lacunæ, and occasionally canals. Diœcious. Polyps immersed in a thick cœnosarc, which forms a massive expansion.

Palythoa Howesii, H. & S.

Palythoa Howesii, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 693; Pl. LXI., fig. 13; Pl. LXIII., fig. 8.

Form.—Polyps scarcely projecting above the surface of the cœnosarc when contracted, and then, in most cases, only one side is prominent. Cœnosarc thick, incrusting; the polyps are arranged in indefinite, roughly parallel rows; owing to the partial immersion of the polyps, the prominent portion of contiguous polyps have a tendency to form zigzag lines; the whole surface is very rigid and tough.

Colour.—Sandy.

Dimensions.—Average diameter of polyps 7 mm.

Locality.—Fringing reef, Thursday Island.

Palythoa Kochii, H. & S.

Palythoa Kochii, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 694; Pl. LXI. fig. 12; Pl. LXIII., fig. 9.

Form.—Polyps projecting slightly above the surface of the cœnosarc in contraction; cœnosarc incrusting, of moderate thickness. Polyps so crowded as to usually have a polygonal contour; twenty capitular ridges and furrows; tentacles forty in number.

Colour.—Cœnosarc finely speckled buff and cream; disk very finely dotted with brown and opaque white; capitular ridges white.

Dimensions.—Diameter of polyps about 5 mm.

Locality.—Fringing reefs, Thursday Island, and Mabuiag.

Palythoa cœsia, Dana. (?)

Palythoa cœsia, Dana. (?) Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV.; Pl. LXI. fig. 14; fig. 2, p. 696; Saville-Kent, "The Great Barrier Reef of Australia," 1893, p. 152, chromo pl. iii., fig. 1.

Form.—Polyps slightly projecting above the surface of the cœnosarc when contracted; cœnosarc incrusting, of moderate thickness; polyps large, not crowded, of rounded contour; about twenty capitular ridges.

Colour.—Greyish white in spirit specimens. (Varying shades of rich creamy yellow, the minute tentacles being a "more distinct brown," S.-K.)

Dimensions.—Diameter of polyps about 9 mm.

Locality.—Reefs, Torres Straits.

SPHENOPUS, Steenstrup, 1856.

Free, solitary, brachycnemic Zoantheæ, with a single, very long, mesoglœal sphincter muscle. The body-wall is incrusted. Cell-islets present in the mesoglœa.

Sphenopus arenaceus, Hertw.

Sphenopus arenaceus, Hertw., 1882. Voy. H. M. S. "Challenger," Zoology; Rep. on Actiniaria, p. 120; Pl. II., fig. 10; Pl. XIV., fig. 8; and Supplement, p. 52; Hadd. and Shackl. 1891. Trans. R. D. S., p. 697.

Form.—Pyriform, non-pedunculate; tentacles small, pointed, about sixty in number, in two cycles; thirty perfect and thirty imperfect mesenteries.

Colour.—Brown-red (in spirit).

Dimensions.—Length, 45 mm.; breadth, 28 mm.

Locality.—Prince of Wales Channel, 6 faths. ("Challenger," Station 187.)

No characters are given, except the colour, by which this species can be distinguished from *S. marsupialis*, Steenstr.

Sub-family II.—MACROCNEMINÆ, Hadd. and Shackl., 1891.

Zoantheæ in which the sulcar element of the primitive sulco-lateral pair of mesenteries (cnemes) is perfect.

PARAZOANTHUS, Hadd. and Shackl., 1891, p. 653.

Macrocnemic Zoantheæ with a diffuse endodermal sphincter muscle. The body-wall is incrusted. The ectoderm is continuous. The mesoglœa contains ectodermal canals, an encircling sinus, lacunæ, and cell-islets. Diœcious. Polyps connected by their cœnosarc.

Parazoanthus dichroicus, H. & S.

Parazoanthus dichroicus, Hadd. and Shackl., 1891; Trans. R. D. S. (2) IV., p. 698; Pl. LXI., fig. 15; Pl. LXII., fig. 5; Kwietniewski, 1897, Abhandl. Senckenberg. Naturf. Gesellsch. XXIII., p. 341. (Ternate.)

Form.—Body short, incrusted with sand and spicules; capitulum with about eighteen distinct ridges; cœnosarc incrusting a specimen of *Plumularia Ramsayi.*

Colour.—Body and cœnenchyme grey; capitulum pale yellow.

Dimensions.—2–2·5 mm. high; 1·25–1·5 mm. in diameter.

Locality.—Channel between Mer and Dauar, about 20 faths.

Parazoanthus Douglasi, H. & S.

Parazoanthus Douglasi, Hadd. and Shackl., 1891; Trans. R. D. S., (2) IV., p. 700; Pl. LXI., figs. 16–22; Pl. LXII., fig. 6.

Form.—Body when growing on Hydroids often somewhat long, and relatively narrow, but when growing on a flat surface usually short and thick; capitular ridges not well marked; texture gritty; cœnosarc incrusting.

Colour.—Sand colour.

Dimensions.—Largest specimens, 8–9 mm. in height; 2–2·5 mm. in diameter; the shorter specimens growing on flat surfaces, 3–5 mm. and 2 mm. respectively.

Locality.—Albany Pass, 10 faths.

GERARDIA, Lac.-Duth.

Macrocnemic Zoantheæ with a diffuse endodermal sphincter muscle. The body-wall is incrusted. The ectoderm is continuous. The mesoglœa contains ectodermal canals, an encircling sinus, and cell islets. The cœnosarc secretes a well-developed, much branched, horny skeleton.

G. Savalia.

The Zoanthean affinities of this interesting form, which was usually regarded as allied to the Antipatharia, were first demonstrated by Carlgren ("Ueber die Gattung Gerardia, Lac.-Duth." Öfvers. Kongl. Vet. Akad. Förhandl., Stockholm, 1895, p. 319). He pointed out that the only distinction between this genus and Parazoanthus was in the secretion of a black, branched, horny, cœnenchyme. From some slides that were prepared by the late Dr. George Brook, I have been able to confirm Carlgren's statements. The only doubt in my own mind is whether the cœnenchyme is really secreted by the polyps, or whether they merely utilise the skeleton of a dead Gorgonian.

EPIZOANTHUS, Gray, 1867. (Not recorded from Torres Straits.)

Macrocnemic Zoantheæ, with a single mesoglœal sphincter muscle. The body-wall is incrusted. The ectoderm is usually continuous, but may be discontinuous; cell-islets in the mesoglœa. Diœcious polyps, connected by cœnenchyme, which may be band-like, incrusting, or greatly reduced, as in the free form.

Platyzoanthus mussoides, Saville-Kent, 1893; "The Great Barrier Reef of Australia," p. 155, with figure.

It is unfortunate that Mr. Saville-Kent has allowed his enthusiasm for novelties to run away with his discretion, and at the same time to indulge in the reprehensible practice of publishing new genera and species without diagnosing them. A glance at the outline sketch given by the author is sufficient to show that the supposed new type is no Zoanthean at all. The description is too imperfect to allow of certainty of identification, but the form is probably a species of Actinotryx (cf. p. 480).

I have brought my earlier studies on the Torres Straits Zoantheæ up to date, and for the sake of convenience I have retained the original order. Taking the mesenteries into consideration, the Brachycneminæ may be regarded as slightly more primitive than the Macrocneminæ; on the other hand Parazoanthus has the simplest sphincter muscle and Zoanthus the most complex; this would, therefore, reverse the order given above. If we regard the Brachycneminæ as having retained the more primitive arrangement of the mesenteries, then the mesoglœal position of the sphincter muscle has been independently arrived at in the two groups. One genus (Parazoanthus) of the higher group (Macrocneminæ) having retained the primitive diffuse endodermal sphincter, while one genus (Zoanthus) of the lower group (Brachycneminæ) has acquired a double mesoglœal sphincter.

I would call attention to two recent papers—one by Mr. Duerden and myself (Trans. R. D. S., 1896, p. 139), in which five new species of Zoantheæ are described, and the other by Mr. Duerden (Trans. R. D. S., 1898, p. 329)—in which he deals with the Zoantheæ of Jamaica.

Tribe IV.—PROTACTINIÆ (McMurrich, 1891) = PROTANTHEÆ (Carlgren, 1891).

Actiniaria "with twelve primary mesenteries; with one, or a pair, or two pairs of secondary mesenteries on each side of the sagittal axis, the increase in number of the secondary mesenteries occurring from the dorsal towards the ventral side." (McMurrich, 1891: "The Phylogeny of the Actinozoa," p. 161.)

"Anthozoa, with twelve primary mesenteries, of which eight at least are perfect, and which are arranged in pairs; the longitudinal mesenteries of each pair being on the faces of the mesenteries which are turned towards the intramesenterial space, except in the case of two pairs, the directives, situated at the extremities of the sagittal axis of the stomatodæum, whose longitudinal muscles are on the faces of the mesenteries which look towards the adjacent intermesenterial space. In addition to these primary mesenteries, secondary mesenteries are also present; of these there may be one on each side, situated in the sulculo-lateral intermesenterial space, or a pair on each side in the same intermesenterial space, or two pairs on each side in the sulculo-lateral and lateral intermesenterial spaces. The development of the mesenteries is upon a bilateral plan." (McMurrich, 1893, p. 137.)

" Actiniaria, with paired mesentaries, arranged according to the Hexactinian plan. Body-wall and œsophagus with ectodermal ganglionic—and muscular—layers." (Carlgren, 1893, p. 23.)

Carlgren and McMurrich proposed the names Protantheæ and Protactiniæ respectively for a new tribe of Actiniaria about the same time, and included more or less the same forms. Later (1893, p. 136) Carlgren thus criticises the definition of McMurrich, which I have just given. " It appears to me that the characters which McMurrich has given to it are not good, and do not well differentiate the Protactiniæ from the Halcampidæ."

The points at issue appear to be these:—

McMurrich emphasises the arrangements of the mesenteries in Scytophorus, Gonactinia, and Oractis, and regards the series of gradually increasing complexity as exhibited in these genera respectively as of prime importance; although, as a matter of fact Scytophorus is a somewhat divergent type.

Carlgren rather dismisses these as phases of the Hexactinian type; doubtless he would willingly admit their probable phylogenetic significance, but he was struck with what he considers to be a more fundamental character in the forms he more particularly studied, which is the possession of nervous and muscular layers by the ectoderm of the body-wall and œsophagus. This is an undoubtedly ancestral character which has been transmitted from the Scyphistoma-like ancestor, and it is this that Carlgren makes of prime importance in his diagnosis.

So impressed is Carlgren with the value of this character that wherever it occurs he would place that form within this tribe. For example, ectodermal muscles occur in the body-wall of Corallimorphus and of Corynactis—thus he makes the Corallimorphidæ (=Corynactidæ) a family of the Protantheæ. When I was preparing for the press a joint Paper with Mr. Duerden, " On some Actiniaria from Australia and other Districts " (Trans. R. D. S. VI., 1896), on my own authority and without consulting Mr. Duerden, I adopted this classification of Dr. Carlgren's. On the whole I prefer to retain the older view which places that family among the Stichodactylinæ.

Dr. Fowler (Quart. Jour. Micr. Sci. xxix., 1889, p. 143) described a new form which he called *Thaumactis medusoides.* Owing to the extreme retraction of his specimen, and other causes, Dr. Fowler was misled concerning it, and thought it was a new type of Actiniarian; Mr. Duerden and I, however, showed that, save for the ectodermal muscle fibres in the capitulum and œsophagus, this form was evidently allied to Alicia and Cystiactis, and therefore belonged to the Aliciidæ.

While acknowledging with Carlgren the phylogenetic importance of the presence of ectodermal muscle fibres in the body-wall of certain sea-anemones, I do not think we are at present justified in making this the sole diagnostic character of a prime group of the Actiniaria. On the whole, I am more inclined to lay stress on the arrangement of the mesenteries, and the nature and position of the tentacles, although, on the other hand, either of these characters cannot be always implicitly relied upon.

Perhaps all the Protactiniæ (Protantheæ) have ectodermal muscles; but, according to my position, certain forms belonging to other groups may also possess them, in which case it will probably be found that these are the lowest, *i.e.* the least specialised members of those several groups.

We must face the difficulty in a systematic study of the Actiniaria, as in other classifications, of allied forms which refuse to be comprised within a diagnosis that will comprise these alone, owing to the fact that some of them possess characters which others do not, and which ally them to another group or even to diverse groups.

Unfortunately McMurrich and Carlgren synchronously proposed their several names for this tribe, so that it is difficult to determine which has the priority. Putting aside the precise date of publication I am inclined, for the above mentioned reasons, to adopt McMurrich's name.

Family.—GONACTINIIDÆ., Carlgren, 1893.

Gonactinia,	M. Sars, 1851 (cf. Carlgren, 1893, p. 31).
Oractis,	McMurrich, 1891, p. 135 (cf. 1893, p. 138).
Protanthea,	Carlgren, 1891, p. 81 (cf. 1893, p. 24).
? *Scytophorus,*	Hertwig, 1882, p. 104 (cf. McMurrich, 1891, p. 134; 1893, p. 140).
? *Halcurias,*	McMurrich, 1893, p. 142 (cf. Carlgren, 1893, p. 136).

Tribe V.—HEXACTINIÆ, R. Hertwig, 1882.

Actiniaria, with usually six, but there may be eight or ten, pairs of perfect mesenteries which form the primary cycle, and to which may be added a varying number of additional cycles, perfect or imperfect, the mesenteries of which develop in pairs and radially, appearing almost simultaneously in all the intermesenterial spaces. The longitudinal (retractor) muscles of each pair are on the faces which look towards each other; that is, towards the intramesenterial spaces, except in the case of two (occasionally one or more than two) pairs, the directives, in which the longitudinal muscles are on the faces which look away from each other; that is, are turned towards the adjacent intermesenterial spaces.

This, with very slight modifications, is the definition given by M^{c}Murrich (1893, p. 140). To a somewhat similar definition, Carlgren adds:—"Body-wall and œsophagus without ectodermal, longitudinal, muscular, and ganglionic layers." This statement is very generally true; but I am not yet convinced that it is universally so, at least as far as the muscle fibres are concerned. Hertwig's Monauleæ and Paractiniæ are now included in this tribe.

Order I.—ACTINIINÆ, M. Edw., 1857.

Hexactiniæ with simple, similar tentacles, situated at the periphery of the oral disk, the central portion of which is bare. Only one tentacle communicates with each intramesenterial chamber (endocœl).

This order, or sub-tribe, is adopted by Andres, M^{c}Murrich, Carlgren, and others.

Family.—ILYANTHIDÆ, Gosse, 1858; cf. Carlgren, 1893, p. 36.

Actiniinæ with the aboral extremity of the body rounded, and without a pedal disk.

I have adopted Carlgren's definition, which is certainly wide enough; there is no need to repeat his discussion of the group.

Sub-Fam.—HALCAMPINÆ, Kwietn., 1896 (= Halcampomorphinæ, Carlgren, 1893).

HALCAMPA, Gosse.

Ilyanthidæ with six pairs of perfect mesenteries; body divided into capitulum, scapus, and physa; sphincter diffuse, endodermal, or absent; twelve tentacles.

Kwietniewski finds that *Halcampa purpurea*, Studer, has no sphincter. He says: "von einem entodermalen Ringmuskel kann eigentlich nicht die Rede sein. Ebenso gut fehlt auch ein mesodermaler Sphincter" (p. 588). I have recently cut fresh sections of *Halcampa chrysanthellum* and of *H. arenarea*; in neither can I find any trace of a mesoglœal sphincter; but I do find a very feeble diffuse endodermal sphincter, which is slightly more developed in the latter species; but this may be due to its being a larger polyp.

As there is a considerable resemblance in the general appearance of the various members of this group, it is possible that the form I have identified from Malahide, Co. Dublin, as *H. chrysanthellum* (Proc. R. D. S. (N.S.), v. 1886, p. 1; Trans. R. D. S., 1889, p. 355), may not be that species, though I believe it is. If the type species from Cornwall be found to agree with the foregoing, then it would be well to adopt Kwietniewski's sub-family. Should it, however, be shown that it has a mesoglœal sphincter, then Carlgren's sub-family stands, and *H. purpurea*, Stud., *H. clavus*, Hertw., *H. arenarea*, Hadd., and *H. abyssorum*, Dan., must be placed under the genus Halcampomorphe, Carlgren (1893, p. 38), and in the sub-family Halcampomorphinæ. Carlgren suggests *H. clavus*, Hertw., as the type species; it was certainly the first of this group to be anatomically investigated. I would, however, again point out that we have no proof that this form is the same species as *H. clavus*, Quoy et Gaim.

PEACHIA, Gosse, 1855 (Siphonactinia, Dan. and Kor., 1856).

A history of this genus was given by G. Y. Dixon and myself (Proc. R. D. S., 1885, p. 399), and, later (Trans. R. D. S., 1889, p. 338), I alluded again to it. I have nothing more to add at present, except that it falls under the definition of this sub-family, as there is a feeble diffuse endodermal sphincter.

ILYANTHUS, Forbes.

This genus requires investigation. Simon* has recently described what he identified from spirit specimens as *I. partenopeus*, Andr. (Andres, 1883, p. 242). He finds it has forty-eight tentacles (6 + 6 + 12 + 24), which decrease in size from within outwards, and twenty-four pairs of mesenteries (6 + 6 + 12); all of which, more or less, reach the œsophagus, and are fertile, with the exception of the two pairs of directives. There is a very small, circumscribed endodermal sphincter. Two gonidial grooves. No acontia. Andres says there may be ninety-six tentacles and five cycles.

Carlgren informs me that he thinks Eloactis will also be placed here, the type species of which, *E. Mazeli* (Jourd.), has recently been in English waters (W. Garstang: "On some new or rare marine animals recently discovered on the coast of Devonshire." Trans. Devon. Assoc. xxiv., 1892, p. 380).

Sub-fam.—HALIANTHINÆ, Kwietn., 1896 (=Halcampinæ, Carlgren, 1893).

Ilyanthidæ with few perfect mesenteries; imperfect mesenteries present or absent; mesoglœal sphincter; acontia and cinclides wanting. Twelve or more tentacles.

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* J. A. Simon. Ein Beitrag zur Anatomie und Systematik der Hexactinien.—*Inaugural-Dissertation.* München, 1892.

This sub-family includes *H. duodecimcirrata*, M. Sars, according to Carlgren, 1893, p. 38, and *H. arctica*, Carlgr., 1893, p. 45. The foregoing have twelve tentacles. For a Halcampid with mesoglœal sphincter and more than twelve tentacles, Kwietniewski has erected the new genus Halianthella and the new sub-family Halianthinæ, type: *H. Kerguelensis* (Stud.) (= *Edwardsia Kerguelensis*, Studer). Perhaps *Andvakia mirabilis*, Dan., 1890, p. 86, belongs here.

As I have previously mentioned, Carlgren (1893, p. 136) thinks that the genus Halcurias established by M^cMurrich (Proc. U. S. Nat. Mus., xvi., 1893, p. 142) for *H. pilatus* M^cM. is a member for the Protactiniæ (or rather of his Protantheæ).

Family.—Actiniidæ, Gosse, 1858; Andres, 1884; Hertwig, 1888.

(Antheadæ, Hertwig, 1882; M^cMurrich, 1889; Carlgren, 1893.)

Actiniinæ adhering to foreign bodies by a flat contractile base. Column usually smooth, occasionally verrucose towards the upper part, without cinclides. Margin frequently provided with acrorhagi, but may be smooth. Tentacles numerous, usually long. Sphincter muscle, endodermal, diffuse, usually feebly developed. Perfect mesenteries numerous, and all may be fertile, but sometimes the first cycle, and more generally the directives, are sterile. No acontia.

The above definition is with very slight alterations that given by M^cMurrich (1889, p. 17) for the Antheadæ; it is practically the same as that formulated by Carlgren (1893, p. 49). These definitions of this family are based upon that by Hertwig (1882, p. 31). M^cMurrich and Carlgren state reasons why it is preferable to use Hertwig's original term to the names of Actiniadæ, Gosse (1858, p. 416), or Actinidæ, Andres (1880, 1884, p. 180); but in his Supplementary Report (1888, pp. 4, 7) Hertwig adopts Andres' family, which is the exact equivalent of Gosse's original family, the form of the name adopted by Andres being more in accordance with modern usage. Later (1860, p. 148: in reality this was published in the serial part of the *Actinologia Britannica*, that was issued in November, 1858), Gosse retained this family for the genus Actinia, and erected a new family Antheadæ for the genera Aiptasia and Anthea; in the former he included the non-British forms of Nemactis and Phymactis, and in the latter Actinopsis. On the whole it appears to me best to keep the orginal family of Gosse, but with the terminal modification of Andres.

M^cMurrich (1893, p. 134) includes the Antheomorphidæ (Hertwig, 1882, p. 29) "for the present with the Antheadæ." In this I agree with him.

The number and arrangement of the mesenteries, both perfect and imperfect, are very irregular: sometimes the typical Hexactinian arrangement occurs, and probably this is the case in all young forms. It often happens that mesenteries of various cycles reach the œsophagus, and that, too, for the whole or for a variable portion of its length; thus there are mesenteries which are truly perfect, others which are partially so, while the remainder are imperfect. The directive mesenteries appear also to be very variable in number and position. Occasionally only one directive mesentery of a pair may be recognisable, as in a specimen of *A. Dixoniana*; Hertwig (1882, p. 37), and the Dixons (1889, p. 318) have also noted this. The same separation of two directives by the intercalation of incipient mesenteries may occur (ex. *Actinioides Dixoniana* and *A. Papuensis*), as has been described for *Bunodes thallia* by the brothers Dixon (Proc. R. D. S., 1889, N. S., VI., p. 318).

It has been hoped that the disposition of the gonads on the mesenteries might prove of taxonomic importance. That this has some value, especially in some genera and in other families, there can be no doubt, but it as often as not fails in definitiveness in this family, and so cannot at present be relied upon, as is shown by the following Table, in which I have divided all the species of which we have precise information into two groups according to whether their directive mesenteries are fertile or sterile. In both groups are species that have the other mesenteries of the first cycle fertile.

If it is permissible to theorise, I would suggest that fertility of all the mesenteries is the primitive condition; in some the directives have become sterile; in others this has spread to the mesenteries of the first cycle; while in a few forms other cycles have also become sterile, *Bolocera multiporum* representing an extreme case of this tendency.

Fertile directives, . . .	All mesenteries fertile, *Antheomorphe elegans*, *Macrodactyla aspera*;
,, ,, . . .	all perfect mesenteries fertile, *Antheopsis Koseirensis*;
,, ,, . . .	12 perfect mesenteries fertile, *Actinioides Spenceri*;
,, ,, . . .	some perfect mesenteries fertile, *Anemonia carnea*, *Actinioides Dixoniana*.
Sterile directives, . . .	All other perfect mesenteries fertile, *Actinia equina*, *Condylactis passiflora*, *Bolocera occidua*, *B. pannosa*, *Myonanthus ambiguus*;
,, ,, . . .	all mesenteries fertile except 1st cycle, *Bolocera longicornis*, *B. patens*?, *Actinioides Papuensis*;
,, ,, . . .	1st cycle fertile, *Condylactis cruentata*;
,, ,, . . .	4th, 5th, and 6th cycles only fertile, *Bolocera multiporum*.

The diffuse endodermal sphincter muscle is a good character; but even this is not uniform in appearance, that is, if the irregular forms are retained within the family. A series could be made out commencing with Antheomorphe, passing through Anemonia, Actinia, Actinioides, &c., and ending with Myonanthus; but it would be hazardous to suggest that this is a uniformly ascending series, as it is conceivable, though perhaps not probable, that a sphincter might degenerate.

There is a peculiar difficulty in defining the different genera of this family; and I cannot hope that the following arrangement will prove final, though it fairly well expresses the present state of our knowledge.

The family contains the following genera:—

Actinia.
Anemonia.
Condylactis.
Antheopsis.
Actinioides.
Bolocera.
Polystomidium.
Macrodactyla.
Myonanthus.
Antheomorphe.

ACTINIA, Browne.

Actiniidæ with smooth column; capitular margin with large, conspicuous, often brightly-coloured marginal spherules (acrorhagi) which may or may not be furnished with a well-developed battery of nematocysts; tentacles usually rather short; a a broad diffuse endodermal sphincter.

Although, according to Andres (p. 392), Patrick Browne, in 1756, was the first to employ the term Actinia, the genus with its type species was recognisably defined by Linnæus (1766–68, p. 1088), and has been adopted ever since.

The following four species can with certainty be allocated to this genus:—

A. equina, .	Linn. 1768, p. 1088 (= *A. mesembryanthemum*, Ell. and Sol. 1786, p. 4); Gosse, 1860, p. 175; Andr. 1884, p. 182, Simon, 1892, p. 42.
A. cari, . .	D. Ch. 1825, pp. 233, 243; Andr. 1884, p. 187.
A. infecunda, .	McM. 1893, p. 146 (n. n. for *Comactis flagellifera*, Hertw. 1882, p. 32, not of Dana).
A. citrina, . .	(Hadd. and Shackl.) 1893, p. 125.

Actinia citrina (H. & S.).

(Pl. XXII., figs. 1, 2; Pl. XXVI., figs. 1–5.)

Anemonia citrina, Hadd. and Shackl. 1893; Proc. R.D.S. VIII., p. 125.

Form.—Column soft, produced above into a parapet of well-defined spherules; oral disk round when young; margin folded in large specimens, feebly and imperfectly retractile; mouth round, slightly raised, no œsophageal furrows visible; tentacles of moderate length, thin uniform calibre, in three rows, from one to two hundred in number.

Colour.—Column uniform pale lemon-yellow; oral disk and tentacles uniform burnt amber brown, sometimes lighter, sometimes darker; basal portion of tentacles grey or white, this giving an ill-defined greyish margin to the disk.

Dimensions.—Height of column 30–40 mm. ($1\frac{1}{4}$ – $1\frac{1}{2}$ inch); expanse of corona of largest specimen 50 mm. (2 inches); tentacles 15 mm. in length ($\frac{5}{8}$ inch).

Habitat.—Between tides on the seaward side of a mangrove swamp, Mabuiag.

In one of the two largest specimens, there were 200 tentacles and about 80 marginal spherules; and in one of the smallest specimens 80 tentacles and 30 marginal spherules.

The spherules are often very unequal in size, and when so there is no regular arrangement, but several may occur closely packed together in one portion of the circle, while they are widely separate from each other in another part. The angle between the body-wall and the oral disk is very acute; and it is on the summit of the rim thus formed that the marginal spherules are placed. In none of the specimens do the marginal spherules appear to be withdrawn into a circular invagination such as occurs in *Actinia equina.* Internally the spherules are separated from the outer circle of tentacles by a well-marked zone which, in well-expanded specimens, is inclined as much downwards as inwards. The tentacles in large specimens appear to be in two or three rows; they are fairly long, not sharply pointed, and apparently imperforate at the tip.

Inside the tentacles the oral disk is smooth, and horizontal in position. The mouth is central, very small, and usually quite circular. There are no gonidial tubercles. The body-wall, in well-preserved specimens, is quite smooth; in height it is equal to the diameter of the animal. The pedal disk is smooth, and sometimes shows radii corresponding to larger mesenteries.

When a specimen is cut in two vertically, the œsophagus is seen to expand very rapidly, so that the first part of its wall seems to be more horizontal than vertical. (Pl. XXII., fig. 1.) [This is of course due to the small size of the mouth.] The œsophageal wall is marked by grooves and ridges which seem all about equal in size. No marked œsophageal grooves are present.

On further examining a specimen cut vertically one is struck by the entire absence of any sphincter muscle visible to the naked eye. The body-wall thicker in its lower part is seen to become thinner when traced upwards, and to be thinnest of all where it forms the marginal spherules. The upper part of each mesentery, or that part stretched between body-wall and oral disk, is very delicate, and is pierced by a well-marked stoma. (Pl. XXII., fig. 3.) The rest of the mesentery is thicker, but not very muscular.

Transverse sections of one specimen showed between 60 and 70 pairs of mesenteries. Of these some pairs are very small, only about 44 pairs having longitudinal muscular plaitings; about 24 pairs reach the œsophagus. In some cases one mesentery of a pair is much smaller than the other of the same pair. In some places, owing to the extreme irregularity in the mesenteries, it is hardly possible to recognise a distinctly paired arrangement of mesenteries. There seems to be only one pair of directives (?). The muscular plaitings even of the largest mesenteries are not strongly developed, and parieto-basilar muscles seem entirely wanting. In transverse section many of the tentacles show a crenated outline like that seen in *Bunodes thallia.* The longitudinal muscle of each tentacle is ectodermal. It is a curious fact that, in a good many cases, the central cavity of each tentacle is occupied by the termination of a mesenterial filament. The endoderm throughout contains zooxanthellæ which, however, are most numerous in the tentacles. A longitudinal section shows a thin body-wall without endodermal saccules. (Pl. XXVI., fig. 5.) The upper part of wall is thinner and less contracted than the lower part. The thinnest part of body-wall is that which forms marginal spherules; towards the endoderm the mesoglœa is thrown into small plaits, on the sides of which endodermal muscle cells occur. These plaits are most numerous near the lower part of the wall, and are entirely absent in the marginal spherules. (Pl. XXVI., fig. 1.) The thinness of the wall of the spherules is due to diminution in thickness of all three layers. Between the marginal spherules and the outer tentacles there is a well-marked endodermal diffuse sphincter muscle (Pl. XXVI., figs. 2, 3).

Some of the tentacles which are cut obliquely show beautifully both the ectodermal longitudinal and the endodermal circular muscles.

The ectoderm of the disk resembles that of the body-wall, and is slightly folded back and forward on itself. Near the mouth, the ectoderm becomes thicker, and its columnar cells do not reach quite as far as the outer border of mesoglœa, but an intervening space is present which is filled by a fine granular nervous layer similar to that seen in transverse sections of the tentacles (Pl. XXVI., fig. 4) between the ectodermal columnar cells and the mesoglœa.

ANEMONIA, Risso, 1826, p. 288; Andr., 1884, p. 189.

(Anthea, Johnst., 1838.)

Actiniidæ with smooth column; no distinct acrorhagi; tentacles usually long, and not retractile; endodermal sphincter muscle usually feeble, but variable.

There is no doubt that this genus is very closely allied to Actinia. McMurrich

(1893, p. 146) says: "It may be, perhaps, better to unite all the forms of these genera which possess acrorhagi under the genus Actinia, leaving those destitute of such structures and without a distinct collar and fosse in the genus Anemonia." Hertwig (1882, p. 31) distinctly states: "According to my own observations, *Anthea cereus* has marginal spherules, though these do not strike the eye by their bright colours." One species (his *Comactis flagellifera*, 1882, p. 32, which later he named *Anemonia flagellifera*, 1888, p. 5), associated by Hertwig with this genus, has been identified by McMurrich (1893, p. 146) as belonging to the genus Actinia.

The genus thus stands or falls according to whether the puffy capitular rim of *A. sulcata* is to be regarded as being destitute of, or possessing acrorhagi. In other words, we are dealing with a question of degree; and if it be accepted that the distinction between the condition in *A. equina* and *A. sulcata* is not of generic importance, then it appears as if this genus must lapse, unless it be retained for some extreme forms which can be proved to have no capitular vesicular swellings of any kind whatever.

The genus, as at present constituted, has some latitude in the amount of the development of the sphincter muscle. Simon (1892, p. 37), who has apparently only studied *A. sulcata*, describes it as a "feeble, endodermal, circumscribed, sometimes more diffused sphincter."

A. sulcata,	(Penn.), 1766 (*Actinia sulcata*, Penn.; *Actinia cereus*, Ell. and Sol., 1786, p. 2; *Anthea cereus*, Gosse, 1860, p. 160; *Comactis flagellifera*, Dana, 1849); Andr., 1884, p. 190.
A. Contarini,	(Hell.), 1868, p. 18 (*Actinia Contarini*, Hell.; *Anemonia cinerea*, Cont., 1844, p. 183); Andr., 1884, p. 193.
A. (?) *variabilis*.	McM., 1893, p. 147 (this name was withdrawn on p. 208, as McMurrich later supposed it to be the same as *Corynactis carnea*, Stud.). Kwietniewski has recently (1896, p. 597) shown that Studer's form is a true Corynactis, therefore McMurrich's original name stands.
A. (?) *inequalis*,	McM., 1893, p. 149.
A. Ramsayi,	(H. and S.), 1893, p. 124.
A. Kwoiam,	H. and S., 1893, p. 125.

Anemonia Rámsayi (H. & S.).

(Pl. XXII., figs. 3, 4; Pl. XXVI., figs. 6, 7.)

Condylactis Ramsayi, Hadd. and Shackl., 1893, Proc. R. D. S., VIII., p. 124.

? *Gyrostoma Hertwigi*, Kwietn.*

Form.—Column soft, about as high as broad, terminating above in a well-marked parapet, but without marginal spherules or suckers; disk flat, considerably wider than the column, can be slowly but completely retracted; mouth circular, with a variable number of gonidial grooves (2–7); tentacles numerous, relatively short, about one-third of the diameter of the disk.

Colour.—Column usually olive-brown or green, occasionally pale magenta pink; disk translucent, olive-brown or cinder colour; stomatodæum whitish;

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* I venture to give *Gyrostoma Hertwigi*, as a synonym of this species; but as will be seen from the following translations of Kwietniewski's definitions (Ein Beitrag Zur Anat. Syst. Actin., Inaug.-Dissert. Jena, 1897, pp. 27, 30), he regards this form as the type of a new tribe of Actiniaria. It does not appear that more than one specimen was examined, and I can testify as to the variability that occurs in the number of the directive mesenteries.

Tribe.—ISOHEXACTINIÆ, Kwietn.

Actiniaria, with numerous paired mesenteries, which are arranged with radial symmetry on the hexradiate type. With six pairs of primary mesenteries, all of which bear longitudinal muscles on the sides turned away from each other. The remaining pairs of mesenteries have their longitudinal muscles on the sides turned towards each other. The body musculature consists of an endodermal circular muscle layer; the ectodermal musculature is confined to the oral disk.

Family.—GYROSTOMIDÆ, Kwietn.

(With the characters of the Tribe.)

GYROSTOMA, Kwietn.

Gyrostomidæ, with a smooth body-wall, the upper border of which is raised into a distinct fold. The oral disk wide, round, provided with short, conical, pointed tentacles, which are arranged alternately, not in rows. Mouth round. The cylindrical œsophagus with six siphonoglyps. Mesenteries numerous, mostly perfect; all the mesenteries of the higher cycles provided with gonads and mesenterial filaments. A feeble, diffuse, endodermal sphincter muscle.

Gyrostoma Hertwigi, Kwietn.

Thursday Island, Torres Straits; collected by Prof. R. Semon.

tentacles, with a grayish-brown core and a green satin-like sheen, sometimes with a pale ring near the tip, or with the tip of a paler and brighter green.

Dimensions.—Height of column about 38 mm.; diameter of oral disk about 46 mm.

Habitat.—Reef, Waier (Murray Islands).

The ectoderm of the body-wall not well preserved; but, where present, appears to consist of granular and indistinct cells. The mesoglœa is thick, and contains numerous darkly-stained nuclei similar to those in the endoderm; they are generally surrounded by a narrow zone of mesoglœa, which is less deeply stained than the neighbouring mesoglœa.

The endodermal sphincter muscle (Pl. XXVI., fig. 6) is very feeble, and consists of a group of five or six plaits, some of which are slightly branched.

Tentacles.—The nuclei of the ectoderm cells are diffusely scattered. The nematocysts are very distinct. The muscle layer is well developed. The endoderm is crowded with zooxanthellæ.

There are about thirty-three pairs of non-directive mesenteries in the specimen investigated, many of which are perfect. The arrangement of the mesenteries is extremely irregular, and no symmetry could be discovered. There are four pairs of directive mesenteries, of which one pair is more strongly developed than the others. There are four œsophageal grooves corresponding to the directives, and their œsophageal lappets extend nearly to the base of the cœlenteron.

The longitudinal muscles of the mesenteries are well developed; the mesoglœal folds are slender, and ramify but little; the muscle-fibres nearer the wall are less developed. (Pl. XXVI., fig. 7.) Basal muscles on small pennons, on opposite side of mesentery to the longitudinal muscles, are present in the larger mesenteries. The mesoglœa of the mesenteries is thick, and contains nuclei similar to those in the body-wall. The mesenterial filaments are much twisted and coiled; thread-cells and clear oval cells present among the columnar cells; the latter contain deeply-staining nuclei.

No gonads occurred in the specimen examined.

Anemonia Kwoiam, H. & S.

(Pl. XXII., fig. 5; Pl. XXVI., figs. 8–11.)

Anemonia Kwoiam, Hadd. and Shackl., 1893; Proc. R. D. S. VIII., p. 125.

Form.—Body, salver shaped, smooth; upper portion of column without suckers, when fully expanded extends beyond the insertion of the tentacles, and forms a distinct crenulated rim; disk of much greater diameter than column, with a wavy margin; mouth round, no gonidial grooves; tentacles in multiples of six.

Colour.—Column, buff; disk, burnt sienna brown, with several white radial lines near the mouth corresponding to the primary radii; remainder of disk blotched with white, especially peripherally; tentacles brown, speckled with white proximally.

Dimensions.—Corona, 155 mm. (about 6 in.), when fully expanded; tentacles, 22 mm. long.

Habitat.—Surface of reef, Mabuiag (Jervis Island).

Longitudinal sections of the column show that the ectoderm is thrown into numerous folds, and here the mesoglœa is also thicker, and the plaits of the endodermal muscle are much more evident (Pl. XXVI., fig. 11). The uppermost portion of the body-wall is thin and regular, and in vertical sections (Pl. XXVI., fig. 8) forms a vesicular bulging; this is the crenulated rim referred to in the diagnosis of the species. At the oral origin of this loop, and immediately opposite the spot where the folded body-wall becomes smooth, is the diffuse sphincter.

The endodermal sphincter is so feeble as to be quite insignificant. It consists (Pl. XXVI., figs. 8, 9, 10) of two or three small plaits of the mesoglœa which are simple or with one or two branches.

There are from 50 to 60 pairs of mesenteries of various sizes, most of which are gonophoric. The retractor muscle is strong and consists of very numerous plaits which are long, fine, and but slightly branched. There is no pennon muscle.

CONDYLACTIS, Duch. et Mich., 1866; M^cM., 1889, p. 18.

Cereactis, Andr., 1884; Carlgr. 1893, p. 49.

Actiniidæ, with the column smooth or slightly verrucose towards the upper part; capitular margin elevated slightly, so as to form a collar or parapet not provided with acrorhagi.

M^cMurrich has proved that the type species of this genus, *Condylactis passiflora*,

D. & M., belongs to this family. He states that the young of this species have verrucæ which disappear in the adults, in this case it is very difficult to draw up a definition which will distinguish between this genus and Anemonia.

The following species may for the present be regarded as belonging to this genus:—

C. passiflora, . . .	Duch. & Mich., 1866; McM., 1889, p. 18; 1896, p. 181. (*Bunodes passiflora*, Andr., 1884, p. 231.)
C. aurantiaca, . . .	(D. Ch.), 1825, p. 438 (*Actinia aurantiaca*, D. Ch.; *Cereactis aurantiaca*, Andr., 1884, p. 238.); McM., 1889, p. 21.
C. erythrosoma, . .	(Ehr.), 1834, p. 33 (*Actinia Isacmæa erythrosoma*, *Urticina*, H. & E., Ehr.; *Paractis erythrosoma*, Klunz., 1877, p. 69; *Anemonia erythrosoma*, Andr., 1884, p. 195); McM., 1889, p. 21.
C. cruentata, . . .	(Dana), 1884 (*Actinia cruentata*, Dana, pl. 3, fig. 23; *Bunodes cruentatus*, Andr., 1884, p. 215); McM., 1893, p. 150.

ANTHEOPSIS, Simon.

Actiniidæ with the column smooth below and with suckers above, with a well developed capitular rim (parapet), and numerous long tentacles of which most arise from the greater part of the surface of the greatly expanded oral disk; feeble endodermal "circumscribed" sphincter.

Simon (1892, p. 30) has constituted this new genus for "*Bunodes Koseirensis*, Klunz. (1877, p. 77, pl. vi., figs. 1, 2). These tentacles are in numerous cycles (6 + 6 + 12 + 24 + 48 + 96 = 192); the pairs of mesenteries are similar in number and order to the tentacles; there are two pairs of directives; the first three cycles reach the œsophagus to a greater or less extent; all the larger mesenteries, including the directives are fertile"; "the small ('circumscribed') sphincter is very similar to that of *Anemonia sulcata*." This last comparison makes it clear that Dr. Simon does not make use of the term "circumscribed" in precisely the same sense as it is usually employed in Actiniarian studies, *i.e.* for the sphincter that is characteristic of the Bunodidæ or *Urticina* (*Tealia*) *crassicornis*, for example.

A. Koseirensis (Klunz).

ACTINIOIDES, H. & S.

Actiniidæ with more or less prominent suckers on upper portion of column; capitular margin with conical acrorhagi; diffuse or feebly circumscribed endodermal sphincter muscle.

This genus bears somewhat the same relation to the genus Actinia, that Condylactis does to Anemonia.

A. Dixoniana, Hadd. & Shackl., 1893, p. 126.
A. Sesere, Hadd. & Shackl., 1893, p. 126.
A. Spenceri, Hadd. & Duerd., 1896, p. 159.
A. Papuensis, n. sp.

Actinioides Dixoniana, H. & S.

Actinioides Dixoniana, Hadd. and Shackl., 1893, Proc. R. D. S. VIII., p. 126.

(Pl. XXII., fig. 6; Pl. XXVII., figs. 1, 2.)

Form.—Column, covered with vertical rows of sucker-like verrucæ; capitular margin provided with large conical acrorhagi; tentacles in two cycles, *not* in multiples of six; sphincter muscle feeble but slightly circumscribed.

Colour.—Column, various shades of greenish grays and browns in vertical lines; tentacles, olive-brown, banded with greenish white or grey on oral aspect; acrorhagi, yellowish; disk, dark greenish brown, with white markings; lips of mouth with white radial lines, a brown ring round the mouth.

Dimensions.—Diameter of corona of largest specimen, 31 mm.; length of tentacles, 10 mm.

Habitat.—Fringing reef, Mabuiag.

Body-wall.—Very similar in character to the following species, but mesoglœa thicker, and endoderm thinner in proportion to ectoderm. Endodermal muscular layer with well developed mesoglœal plaitings. Neither warts nor ridges apparent in transverse sections. The marginal spherules or acrorhagi (Pl. XXVII., fig. 1, acr.) are composed principally of the greatly thickened ectoderm, the cells of which are very tall and slender.

The short diffuse endodermal sphincter muscle consists of about four simple or slightly branched plaits of mesoglœa, flanked by a few small, simple plaits; the mesoglœa is also thickened in this region.

Tentacles with a slight transverse fluting. The ectoderm and endoderm are very thick, but the mesoglœa is very thin. Ectoderm similar to that of *A. Papuensis*, the mesoglœal plaiting of the ectoderm muscular layer is very prominent and distinct.

Disk very similar to tentacles, but plaitings less marked.

Mesenteries.—Longitudinal muscles very well developed (Pl. XXVII., fig. 2); pennons somewhat larger than in *A. Papuensis.* The basal muscle on the same side as the longitudinal muscle also well developed. Filaments much convoluted appear to consist of numerous rays or branches; the epithelium at the ends of these resembles more nearly the ectoderm of the œsophagus than the remainder.

Gonads on most of the mesenteries, the directives may be fertile.

Specimen A.—This male specimen possesses two well-marked pairs of directives and an obscure directive area, in which only one directive is well developed, and twelve pairs of non-directives. One pair of directives is infertile; on each of it is a pair of small mesenteries; the pair on the one side appears first (in a series of sections from above downwards), but it never possesses mesenterial filaments; the pair on the other side do not extend beyond the endoderm. Next to this pair is a pair of which the one nearer the directives is small and infertile, whereas the other is large and fertile; a large pair of fertile mesenteries follows, and then comes a pair of fertile directives. This is followed by three pairs of fertile mesenteries; the next is a well developed directive mesentery, which is fertile in its lower portion. Two peculiar mesenteries follow; they are very thin, and much folded; they have no longitudinal muscles, but their small pennon muscles look towards one another; these follow two very inconspicuous incipient mesenteries, which are followed by another singular mesentery, also very thin and folded, with no longitudinal or pennon muscles, but it appears to be fertile at the very base of the polyp; this may be an undeveloped pair to the single directive. Two large fertile pairs of mesenteries follow, and then a pair of which the element nearer to the infertile pair of directives is small and infertile, whereas the other is large and fertile; between this pair and the infertile directives is the rudimentary pair of mesenteries mentioned above.

The formula of this specimen may be written thus:—

$$D\,3\;D\,3\;d\,2\;d\,4 = 15.$$

I have taken the two (?) half-directives as forming one pair in the total of fifteen pairs of mesenteries.

Specimen C.—This specimen has five pairs of directives and thirteen pairs of non-directives; the mesenterial formula is

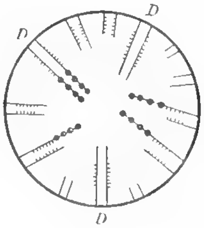
$$D + 2 + D + 2 + D + 2 + D + 2 + D + 5 = 18.$$

One pair of the second series of two pairs is rudimentary, and one or two of the other mesenteries are smaller than their fellows, but nothing of interest was noted in their variations. Gonads (testes) appeared to be present on only one mesentery, and that was on one of the central pair of the group of five.

Specimen D.—This male specimen has three pairs of directives and ten pairs of non-directives. The mesenterial formula is

$$D + 3 + D + 2 + D + 5 = 13.$$

The arrangement of the gonads is so peculiar that it is illustrated by the accompanying figure, which will give a better idea than a long verbal description. The figure is diagrammatised, in order to indicate the main points more clearly. It will be seen that only one pair of directives is fertile; if we assume that this and one of the other pairs are the original axial directives, and that the fertile pair is the sulcular pair, then the fertile non-directive mesenteries, can, to a certain extent, be brought into relation with those in Edwardsia; if we also assume that pairs of mesenteries may develop somewhat irregularly in various exocels. The arrangement of the mesenteries on each side of the sterile directives in *specimen A* is somewhat analogous. There may not be anything in this comparison; but, on the other hand, we can only get a true conception of mesenterial arrangement by bearing in mind the order of their appearance.



Actinioides Papuensis, n. sp.

(Pl. XXII., fig. 7; Pl. XXVII., figs. 3–7.)

Form.—Column with verrucæ arranged in vertical rows; the acrorhagi are prominent, and appear to be alternately slightly larger and smaller. Sphincter very feeble diffuse.

Dimensions.—Of spirit specimen about six-sevenths of an inch in diameter.

Habitat.—On the shore near a mangrove swamp, Mabuiag.

Unfortunately there is not among my notes a description of the animal when alive, nor any figure of it. The contracted spirit specimens show nothing which is at all distinctive in character, and they resembled, on the whole, *Actinioides Dixoniana.* Reliance must therefore be placed on the character of the sphincter muscle for specific diagnosis.

Body-wall.—The ectoderm of the body wall usually has a scalloped appearance due to contraction; clear, somewhat pear-shaped cells are very numerous. The mesoglœa is not as thick as the ectoderm, and is slightly implicated in the ectodermal scallops; it stains deeply. The endoderm is as thick as the ectoderm and mesoglœa together, and is crowded with zooxanthellæ.

Sphincter.—The diffuse endodermal sphincter is very feebly developed (Pl. XXVII., fig. 3). It consists of about a dozen plaits, which are mostly quite simple.

Acrorhagi.—The marginal spherules are simply vesicular prolongations of the capitulum, and possess no distinctive features; no traces of pigmentation occur in the ectoderm in the sections.

Tentacles.—The ectoderm and endoderm are of about equal thickness; the mesoglœa is slightly plaited on its ectodermal surface. The ectoderm stains deeply, but the nervous basal layer is clear; the nematocysts are small. The endoderm contains numerous zooxanthellæ.

The ectoderm of the œsophagus is thrown into numerous folds; the cells are granular and ciliated, especially in the grooves, which are variable in number.

Mesenteries.—The mesoglœa of the mesenteries is relatively thick; a strong prominent retractor muscle is present (Pl. XXVII., fig. 4); the plaitings are long and usually slightly branched: the basal muscle fibres on the same side are but slightly developed. On the opposite side of the mesentery the strong parieto-basilar muscle is produced into a well-developed pennon.

The filaments which are only borne by the perfect mesenteries are continuous with the ectoderm of the œsophagus. The œsophageal grooves are continued a long way down towards the base of the polyp.

The number and arrangement of the mesenteries is very varied, as is shown in the following table:—

2 grooves,	2 pairs of directives.	14 pairs of non-directives,	= 16
3 ,,	3 ,, ,,	10 ,, ,,	= 13
3 ,,	4 ,, ,,	14 ,, ,,	= 18

or to write it in another way,

$$D + 6 + d + 2 + d + 6 = 16^{*}$$

$$D + 4 + D + 2 + D + 4 = 13$$

$$D + 2 + D + 2 + D + 3 + D + 7 = 18$$

The character and size of the several mesenteries are indicated in the figures (Pl. XXVII., figs. 5, 6, 7). The directives D^1 in fig. 5 enclose two other pairs

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* In this formula *d* stands for one mesentery of a pair of directives.

of mesenteries; of these, those nearest to the directives would probably later have formed complements to those directives, and so two pairs of directives would result. This is probably what has occurred for directives, D^3 D^4 of fig. 7.

Gonads.—Any of the larger mesenteries may be fertile, including those that evidently belong to the primary cycle. In one female specimen the four pairs of directives are fertile, but in other specimens no gonads could be discovered with certainty on the directives.

This species is certainly nearly allied to *A. Dixoniana*, but I think it is a distinct species.

Actinioides Sesere, H. & S.

(Pl. XXII., figs. 8, 9; Pl. XXVIII., figs. 1–2.)

Actinioides Sesere, Hadd. and Shackl., 1893; Proc. R. D. S., VIII., p. 126.

Form.—Column, smooth, with about 24 vertical rows of verrucæ, which are small below, in the upper portion of the column these are larger, and somewhat irregular in their arrangement; capitulum, provided with well-defined, conical acrorhagi (Pl. XXII., fig. 9); disk flat; mouth round, raised on small cone, with no gonidial grooves.

Colour.—Column various shades of brown and gray; verrucæ bright green; acrorhagi light green, with dark spots; tentacles, inner rows brown and faintly banded, outer row brownish white, with green sheen, with a black spot at their base; oral disk brown, with white or pale green radial lines, which usually unite in a spot at the base of the tentacles.

Dimensions.—Height of column 10 mm.; diameter of corona 30 mm.

Habitat.—Crevices and holes in stones on the shore, Mabuiag.

Externally this species can be readily distinguished from the other species of the genus; the general green colour and the bright green spots are very characteristic.

Sphincter Muscle.—Not less characteristic is the sphincter muscle (Pl. XXVIII., figs. 7, 8); at first sight it looks as if it should be classed as circumscribed; although it is rounded in section, the mesoglœal plaitings do not all arise from a common stem, but there are several main plaits. Of the described species of Actinioides, *A. Papuensis* has the simplest sphincter; then follow *A. Spenceri*, *A. Dixoniana*, and *A. Sesere*, is the most specialised.

BOLOCERA, Gosse, 1860, p. 185; McM. 1893, p. 154; Carlgr. 1893, p. 49.

(Liponema, Hert. 1888, p. 17.)

Actiniidæ with smooth or nearly smooth column; no acrorhagi; with large, extremely easily detachable tentacles which have a distinct circular muscle at their base.

As Carlgren points out, the earlier writers associated this genus with the Antheadæ, but Gosse (1860, p. 185) placed it among the Bunodidæ, in which he was followed by Studer, Andres, and Danielssen. McMurrich (1893, p. 153) erects the new family Boloceridæ for this genus, with the following definition:—"Actininæ with usually stout non-retractile tentacles, strongly constricted immediately above their insertion into the disk, and hence readily deciduous. Sphincter muscle endodermal, diffuse, or in some forms approaching the circumscribed type; the tentacles and disk fully exposed in the contracted condition. With more than six pairs of perfect mesenteries." The genus is credited "with the characters of the family." As the sphincter muscle of the deciduous tentacles is the only peculiar character in the diagnosis just given, I prefer to adhere to the original opinion of Carlgren (whose definition I have adopted), who regarded Bolocera as belonging to the Actiniidæ; but in his Nachschrift (1893, p. 137) he adopts McMurrich's new family. I also agree with McMurrich (1893, pp. 160, 209) that Hertwig's *Liponema multiporum* (1888, p. 17) is a Bolocera; indeed I had independently arrived at the same conclusion. The family Liponemidæ of Hertwig (1882, p. 63) is by no means homogeneous: the genus Polysiphonia (Hertw. 1882, p. 63) has been shown by McMurrich (1893, pp. 165, 209) to be Actinernus, a genus of the Paractidæ. I see no reason why Polystomidium (Hertw. 1882, p. 67) should not range along with Bolocera among the Actiniidæ; Aulorchis (Hertw. 1888, p. 21) is at present insufficiently known; the generative apparatus of the type species *A. paradoxa*, Hert., is unique among the Actiniaria, its sphincter muscle is of the aggregated type described by McMurrich in *Myonanthus ambiguus*, but apparently still more mesoglœal than the latter.

B. Tuediæ, (Johnst.) 1832, p. 163 (*Actinia Tuediæ*, Johnst.; *Anthea Tuediæ*, Johnst, 1847, p. 242); Gosse, 1858, p. 417; Andr. 1884, p, 205; Gosse, 1860, p. 186; McM. 1893, p. 155.

B. eques, Gosse, 1860, p, 351; Andr. 1884, p. 206.

B. Kerguelensis, Stud. 1878, 544; Andr. 1884, p. 206; M^cM. 1893, p. 155; Kwiet., 1896, p. 592.

B multicornis, Verr. 1879, p. 198; Andr. 1884, p. 237; M^cM. 1893, p. 155.

B. multiporum, (Hertw.) 1882, p. 129; 1888, p. 17 (*Liponema multiporum*, Hertw.); M^cM. 1893, p. 209.

B. longicornis, Carlgr. 1891, p. 241; 1893, p. 50.

B. occidua, M^cM. 1893, p. 154.

B. pannosa, M^cM. 1893, p. 156.

B. brevicornis, M^cM. 1893, p. 158.

It is possible, as M^cMurrich has pointed out (1893, p. 153), that Danielssen's new genus and species, *Sideractis glacialis* (1890, p. 14) is a species of Bolocera. Unfortunately Danielssen's description is too vague to be of much value; we cannot even be sure of the nature of the sphincter muscle. The chief character appears to be that the tentacles are multiples of 8 (8 + 8 + 16), and that there are 16 perfect and 16 imperfect mesenteries.

POLYSTOMIDIUM, Hertw., 1882, p. 67.

Actiniidæ, with a smooth, but longitudinally, furrowed column; capitular margin crenulated, with a space between the margin and the tentacular corona; tentacles deciduous; circular muscle endodermal.

I have recast the definition of this genus, as Hertwig describes the crenulations of the capitular margin as "marginal spherules." There is little doubt that acrorhagi have developed from such "small knobs"; but I do not think we can regard these as true marginal spherules. Hertwig's phrase, "tentacles transformed by retrograde formation into stomidia," has been replaced by "tentacles deciduous," as probably being more correct.

This genus appears to be very closely allied to Bolocera; as the tentacles have not been described, we do not know whether they possess the sphincter muscle characteristic of Bolocera. Gosse describes the "margin (of the column of *Bolocera eques*) as forming a thick parapet, the summit obtusely edged, and notched with close-set denticulations," a condition which is not very dissimilar to that figured by Hertwig for Polystomidium. Slight longitudinal furrows have also been noted in some species of Bolocera. Hertwig himself admits that "in their habit of body, in the endodermal position of the circular muscle, and in the presence of the marginal spherules, these animals are allied to the Antheadæ." I am of opinion that this genus should be merged with Bolocera.

P. patens, Hertw., 1882, p. 67.

MACRODACTYLA, n.g.

Actiniidæ, with the upper portion of the column covered with adhesive suckers; no capitular rim or acrorhagi; tentacles long and stout, but not detachable; sphincter restricted; with six pairs of imperfect mesenteries, and a second and third cycle of imperfect mesenteries; all the mesenteries gonophoric.

In the present state of our knowledge it seems necessary to define a new genus for the species formerly described as *Condylactis aspera.* In some respects it resembles one or other of several genera of this family, its combination of characters serving to distinguish it from any one of them.

Macrodactyla aspera (H. & S.).

(Pl. XXII., figs. 10, 11; Pl. XXVIII., figs. 3–5.)

Condylactis aspera, Hadd. & Shackl., 1893; Proc. R. D. S., VIII., p. 124.

Form.—Column cylindrical; skin delicate; the whole of the body except the disk covered with small, very adhesive suckers, so that whenever touched, this Actinian adheres to a foreign body like a Synapta; fragments of shells adhere to the body; large suckers occur on the upper portion of the column; mouth elongated; two gonidial grooves; large tentacles in three or four cycles (6 + 6 + 12 + 24 = 48), the inner cycle much the largest; usually the tentacles are considerably swollen, but they can become quite slender and flaccid.

Colour.—Body, uniform pale, translucent yellow, drab or buff, finely dusted with very minute brown spots, many of the suckers opaque white; tentacles translucent buff, slightly darker below, with three indistinct pale bands (one basal and two central); at the base is a dark patch; oral disk a mealy drab, with radial brown (mesenterial) lines, the primary and secondary radii; and to a less extent the tertiary also, with a cloudy mark not far from the base of each tentacle; between this and the dark basal patch of the tentacle is a whitish patch; a dark line round the mouth; œsophagus cream-coloured.

Dimensions.—Column height, 30 mm., or more; diameter about 25 mm. (1 in.); tentacles 60–75 mm. (2½–3 in. long); extreme diameter of corona 175–200 mm.

Habitat.—Surface of reef, Mer.

In longitudinal sections of the column, we find that in the capitular portion of the column the body-wall is very thin, the greater part of the thickness being contributed by the ectoderm; the mesoglœa is thin, and the endodermal plaits are comparatively small and sparse (Pl. XXVIII., fig. 3).

In the region of the suckers, the ectoderm is much folded and very deep at the ends of the suckers. The mesoglœa is greatly thickened, and the plaits for the endodermal muscle are long, very numerous, and often branched. The complex character of these plaitings is most marked round the origin of each sucker, so that practically a local, circumscribed, endodermal sphincter muscle is formed (Pl. XXVIII., fig. 4).

The mesenteries are arranged in the ordinary Hexactinian plan, and consist of 24 pairs (6 + 6 + 12), of which two are directives. They are all fertile. The retractor muscles are large, and consist of a number of simple or but slightly complex plaits (Pl. XXVIII., fig. 5); a strong pennon muscle is present.

The endodermal sphincter is of a form intermediate between the diffuse and the circumscribed types; it might, perhaps, be termed "restricted," whereas the typical circumscribed muscle is "constricted." Its character is best understood by the figure (Pl. XXVIII., fig. 4). It is small for the size of the polyp; the most distal plaits are arranged so as to form a dendritic group.

MYONANTHUS, McM., 1893, p. 151.

Actiniidæ with smooth column; no acrorhagi; aggregated endodermal sphincter muscle.

I have compiled a definition of McMurrich's new genus from the description he has published of a new form which is mainly characterised by possessing a peculiar kind of sphincter, which appears to be a diffuse type which is in process of becoming mesoglœal; for this variety he proposes the name "aggregated." There are several cases known where the first steps, so to speak, in this process have been taken (e.g. *Diplactis Bermudensis*, McM., Proc. Acad. Nat. Sci. Phila., 1889, p. 111), and also in the genus Parazoanthus, but in this genus the process has gone a step further.

McMurrich points out that "this form is not readily referable to any of the recognised families. On the whole, however, it seems to approach more nearly to the Antheadæ than to any of the others" (p. 153).

M. ambiguus, McM. 1893, p. 151.

ANTHEOMORPHE, Hertw., 1882, p. 30.

Actiniidæ with smooth column; capitular margin not forming a collar, and without acrorhagi; tentacles long, in a single row; no sphincter muscle; gonads on all the mesenteries.

I agree with McMurrich (1893, p. 134) in placing the Antheomorphidæ of Hertwig, "for the present, with the Antheadæ" (Actiniidæ).

A. elegans, Hert., 1882, p. 30.

Family.—ALICIIDÆ, Duerden, 1895.

Actiniinæ with a large, flat, contractile base. Column with simple, or compound hollow outgrowths or vesicles over more or less of its surface, arranged mostly in vertical rows. No cinclides; tentacles simple, subulate, and entacmæous. Sphincter muscle endodermal and diffuse, variable in degree of development; perfect mesenteries few or numerous. No acontia.

This family was proposed by Duerden in 1895 (Ann. Mag. Nat. Hist. ser. 6, vol. xv. p. 215), and since then he has thoroughly established it. The arrangement of this family proposed by Duerden and myself (Trans. R. D. S. (2) vi. 1896, p. 154) has been supported by Duerden's last communication (A. M. N. H. (6) xx. 1897, p. 1). I venture to suggest that the genus Phymactis, M. Edw. (1857, p. 274) may be allied to this family; but no anatomical observations have as yet been published on this genus.

The following genera belong to this family:—

Alicia. Thaumactis.
Cystiactis. Bunodeopsis.
Phymactis. (?)

ALICIA, Johns. 1861.

Aliciidæ with very delicate tissues. Column long, beset nearly throughout with vesicles, which may be pedunculate or sessile, compound or simple. Tentacles elongate, more or less retractile; sphincter muscle feebly developed. Six pairs of perfect mesenteries, two pairs of which are directives.

A. mirabilis, Johns. 1861, Madeira; *A. Costæ* (Panc.), 1868, Mediterranean; *A. grandis* (Verr.), 1869, Panama; *A. pretiosa* (Dana), 1846, Fiji; *A. rhadina*, H. & S., 1893, Torres Straits.

Alicia rhadina, H. & S.

Alicia rhadina, Hadd. and Shackl. 1893: Proc. R. D. S., VIII., p. 127.

(Pl. XXIII., figs. 1–8.)

Form.—Columnar, when fully extended, conical when retracted; basal disk flat, adhering; scapus, delicate, with larger and smaller flattish tubercles mainly disposed in vertical series (Pl. XXIII., figs. 1, 6); those at the upper edge of the scapus and below the capitulum are compound stalked tubercles (Pl. XXIII., figs. 1, 7); capitulum delicate, non-tuberculate; oral disk expanded, often crateriform, may be flat, or at times even conical; tentacles 48 in number in two cycles, those of the inner cycle being the longer; mouth oval, with twelve slight ridges, but no gonidial grooves; the whole animal is extremely delicate in texture.

Colour.—Body translucent white, almost transparent; six vertical rows of brown, and six of white tubercles, all of which have a greenish grey apex surrounded by a narrow ring of cream colour; the inner cycle of tentacles transparent and free from colour except a slight tinge of pale pink in some lights, outer cycle similar, but with a bright orange mark at their base, and a dark violet-brown oval spot above it (Pl. XXIII., fig. 5).

Dimensions.—Column, when fully expanded, 30 mm. high, and 17 mm. in diameter.

Habitat.—Albany Pass, Cape York, 10 fms.

I made several sketches of this species when alive, but unfortunately the specimen was lost, and so I have no anatomical observations to offer. There can, however, be very little doubt as to the position of this form, and from the amount of contraction that can take place we may assume that the (? diffuse endodermal) sphincter muscle is fairly well developed.

This species is certainly very nearly allied to the *Actinia pretiosa* of Dana from Fiji (U. S. Explor. Exped., Zoophytes, 1846, p. 137, Atlas, 1849, pl. 3, fig. 20: *cf.* M. Edw., Hist. Nat. Cor. 1857, p. 272, Andres, Le Attinie, 1884, p. 233); but I think it is a distinct species.

CYSTIACTIS, M. Edw. 1857.

Aliciidæ with a column covered with simple vesicles. Tentacles of variable length, in two or three cycles. Sphincter muscle moderately well developed. Numerous perfect mesenteries.

C. Eydouxi, M. Edw. 1857, Chile: *C. Gaudichaudi*, M. Edw. 1857, Rio Janeiro; *C. Reynaudi*, M. Edw. 1857, Cape of Good Hope; *C. tuberculosa* (Q. & G.) 1833, Bass' Straits; *C. Eugenia*, Duch. et Mich., 1866, W. Indies.

THAUMACTIS, Fowler, 1889.

Aliciidæ with irregular scattered complex vesicles, each of which when fully developed is prolonged into an elongated tubular process. Tentacles marginal, about twenty in number. Feeble, diffuse, endodermal sphincter. Ectodermal muscle fibres in capitulum and œsophagus. Two cycles of perfect mesenteries; no œsophageal groove.

T. medusoides, Fowl., 1889. Papeete.

BUNODEOPSIS, Andr. 1880.

Aliciidæ with very delicate tissues. Column short, beset proximally with pedunculate or sessile vesicles, the vesicular area much broader than the column. Tentacles elongate, readily retractile. Sphincter muscle feebly developed; more than six pairs of perfect mesenteries.

B. strumosa, Andr. 1880, Bay of Naples; *B. Antilliensis*, Duerd., 1897, Jamaica; *B. Australis*, n. sp., Torres Straits.

Bunodeopsis Australis, n. sp.

(Pl. XXIII., figs. 9, 10.)

Form.—Body columnar, pedal disk moderately expanded, with a single row of sessile vesicles at base of column. Tentacles relatively very long, entacmæous. Oral disk of greater diameter than column; mouth may be prolonged into a prominent cylindrical cone; no gonidial grooves.

Colour.—Body, oral disk, and cone, translucent white; base of column with yellow streaks; tubercles yellowish, tipped with violet. Tentacles creamy buff, the basal portion of the oral aspect of the two inner cycles (6 + 6) madder-brown, central portion with very fine lemon-yellow spots, giving a granular appearance, distant portion with two very faint brown rings; remaining tentacles paler in colour, without the brown basal mark. Lips of mouth violet.

Dimensions.—Height of column, 3 mm.; length of tentacles, 10 mm.; diameter of oral disk, 5 mm.

Habitat.—Albany Pass, Cape York, 10 fathoms, August 27, 1888.

This is almost certainly an immature form, but I think it is sufficiently characterised to deserve a name. It is probable that additional vesicles appear at the base of the column as the animal increases in size.

Family.—PHYLLACTIDÆ, Andres, 1884.

Hexactiniinæ with a smooth, or more or less verrucose, column, the upper portion of which is produced into tentaculate, club-like, or frondose lobes; the capitulum varies in form and extent; the tentacles are simple and subulate. Sphincter muscle endodermal, variable in amount of development. Two gonidial grooves.

Although it is risky to rely upon external characters in Actiniarian taxonomy, I venture to place together a number of genera which agree in possessing prolongations from the margin of the column. The family was established by Andres

(1884, p. 287) and confirmed by M^c^Murrich in 1889 (Proc. Acad. Nat. Sci. Phila. p. 105) and in 1893 (p. 196).

In his paper on the Actiniaria of the Bahama Islands (1889, p. 55), M^c^Murrich regarded this family as one of the Stichodactylinæ; but very shortly afterwards in a paper on the Actinology of the Bermudas (1889, p. 105), he removed the family to the Actiniinæ, for the very good reason that the sphincter muscle lay between the tentacles and the fronds; the latter thus belong to the category of acrorhagi.

The following genera may be placed in this family:—

Phyllactis. Diplactis.
Oulactis. Hoplophoria.
Cradactis. Asteractis.
Phyllodiscus.

PHYLLACTIS, M. Edw., 1857.

Phyllactidæ with a smooth column and a small oral disk; the acrorhagi are frondose.

Phyllactis prætexta, Dana; *P. cichoracea*, Häck.

OULACTIS, M. Edw. & H., 1851.

Phyllactidæ in which the column is provided with longitudinal rows of verrucæ in its upper part; the fronds are foliose. Sphincter muscle more or less circumscribed.

The above definition is that given by M^c^Murrich (Proc. U. S. Nat. Mus. xvi., 1893, p. 196). This genus appears to differ externally from Phyllactis only by the possession of verrucæ.

O. concinnata (Dana); *O. muscosa* (Dana); *O. flosculifera* (Les.), (= *O. conquilega*, D. & M., Pl. VII. fig. 7; *O. foliosa*, Andr.: *cf.* M^c^Murrich, 1889, Journ. Morph. III., p. 56); *O. formosa* (Duch.); *O. radiata*, D. & M.; *O. ornata* (Verr.), (= *Lophactis ornata*, Verr. *fide* M^c^M. 1893, p. 197); *O. Californica*, M^c^M. (1893, p. 196).

CRADACTIS, M^c^M. 1893.

Phyllactidæ with the fronds represented by bunches of simple or slightly branched, short, tentacle-like structures. Sphincter aggregated or circumscribed. Column with verrucæ.

C. fasciculata, M^c^M. (*Oulactis fasciculata*, M^c^M., 1889, Proc. Acad. Nat. Sci. Phila., p. 108; 1893, p. 197); *C. digitata*, M^c^M., 1893, Proc. U. S. Nat. Mus. XVI., p. 198.

DIPLACTIS, McM.

Phyllactidæ in which the fronds are represented by a single cycle of short digitiform processes, and in which all the mesenteries except those of the first cycle are gonophoric.

McMurrich (Proc. Acad. Nat. Sci. Phila., 1889, p. 110) defines his new genus as above; there is a well-marked diffuse endodermal sphincter between the papillate acrorhagi and the tentacles, the mosoglœal process of the sphincter are rather delicate and anastomose somewhat in their proximal portions. The column is smooth.

D. Bermudensis (McM.), .	(*l. c.* p. 111, 1896, p. 186).
D. delicatula (Hertw.), .	(= *Hormathia delicatula*, Hertw. Suppl. Chal. Rep. 1888, p. 15), *fide* McMurrich.
D. aster (Ell.), . . .	(= *Actinia aster*, Ellis, 1786; D. & M., 1866) McM. 1896, p. 187.
D. depressa (D. & M.), .	(= *Anemonia depressa*, D. & M., 1860) may be the same species as *D. Bermudensis.*

HOPLOPHORIA, Wils. (? Viatrix, D. & M., *fide* McMurrich).

Phyllactidæ with a pedal disk. Column smooth, without cinclides. Capitular margin provided with prominent club-shaped acrorhagi. Tentacles not very numerous, of moderate length; sphincter muscle diffuse, very feebly developed (or absent ?). Six pairs of perfect mesenteries, some of which may be fertile. No acontia.

This genus was instituted, but not defined, by Dr. H. V. Wilson, in 1890, for an Actinian he collected at the Bahamas. McMurrich, however, says: "It seems fairly certain" that this species "is identical with the *Viatrix globulifera* originally described by Duchassaing and Michelotti" (1893, 133, footnote), and again, 1896, p. 186, he makes the same assertion. It was in deference to McMurrich's verbal statement to the same effect that, in the preliminary Report (1893, p. 127) with considerable hesitation, I adopted this conclusion. There is no doubt that Dr. Wilson's species and the present one are closely allied. We must await the rediscovery of *Viatrix globulifera* before this point can be finally settled; but in the mean time I must accept Hoplophoria as a recognised genus. *Viatrix globulifera* appears to me as if it might very well be a young stage of *Cystiactis Eugenia.* (D. & M., 1866, p. 129).

Hoplophoria coralligens, Wilson.
" *cincta* (H. & S.).

Hoplophoria cincta (H. & S.)

Viatrix cincta, Hadd. and Shackl., 1893; Proc. R.D.S., VIII. p. 127.

(Pl. XXIII., figs. 11–15.)

Form.—Tissues very delicate, column short, cylindrical, with a very extensile and variable capitulum; at the junction of the capitulum with the scapus are at least six club-shaped prolongations which may bear tubercles on their aboral aspect; sometimes the capitulum is produced as a broad, thin, horizontal rim round the top of the column, from the margin of which project the club-shaped organs. Tentacles of moderate length in three cycles ($12 + 12 + 24 = 48$).

Colour.—Ectoderm colourless; but the endoderm everywhere shines through with a reddish-brown colour; processes with white ends; tubercles, brilliant green.

Dimensions.—Height of column, 6 mm.; total expanse of capitular rim, about 15 mm.

Habitat.—Surface of reef, Mabuiag, October, 1888.

This is probably an immature form; the specific name is derived from the girdle-like appearance of the capitular rim, beset, as it were, with bosses of emeralds. It appears to be allied to *Hoplophoria coralligens*, Wils.* Professor M'Murrich has, however, informed me that this species is *Viatrix globulifera* (Duch.); but I must confess to seeing but little resemblance between the figures given by Wilson and by Duchassaing and Michelotti.† If Dr. Wilson's species is a *Viatrix*, this must be also placed in that genus.

Only one immature specimen was obtained.

Body-wall.—Thin, especially the ectoderm and mesoglœa. The ectoderm has no distinct muscular layer. The ectoderm, and the acrorhagi, like that of the tentacles, contain very numerous, long, narrow nematocysts and gland cells.

The endoderm is closely packed with zooxanthellæ, which doubtless give to it its distinctive colour. A feeble endodermal muscle layer is present, which is much more marked in the proximal portion of the acrorhagi.

Sphincter muscle.—I cannot be certain that there is any sphincter at all.

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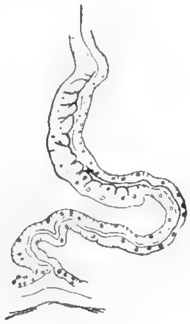
* H. V. Wilson "On a New Actinia, *Hoplophoria coralligens.*" Studies Biol. Lab. Johns Hopkins Univ. IV. Pl. xliii.

† "Mémoire sur les Coralliaires des Antilles." Mem. Reale Accad. Torino (2) XIX. 1860. Pl. vi. figs. 15, 16.

Tentacles.—The ectoderm and entoderm are of about equal thickness, the mesoglœa is very thin. The muscle layer of the ectoderm is not well developed, the endoderm is closely packed with zooxanthellæ.

Œsophagus.—The thick ectoderm of the œsophagus is thrown into half a dozen folds on each side; the gonidial grooves are well marked.

Mesenteries.—There are six pairs of perfect mesenteries, and six pairs of imperfect ones which bear retractor muscles for part of their length; there are also twelve pairs of incipient mesenteries, which consist solely of a strip of mesoglœa that does not extend beyond the endoderm. Their arrangement is typical of the hexactinian plan.



Transverse Section of a Mesentery of *Hoplophoria cincta.* Enlarged about 100 diam.

The retractor muscles are moderately developed; the sparse plaits branch very slightly. Parietobasilar muscles are very weak, and have no mesoglœal plaitings.

The mesenteric filaments are simple; they are very similar to, and apparently continous with, the ectoderm of the œsophagus.

Gonads.—The specimen was immature, and no trace of generative organs could be detected.

ASTERACTIS, Verrill.

Phyllactidæ (?) with a column which is versatile in form; the body-wall is firm and sub-coriaceous; simple, slender, pointed tentacles, tricyclic, forty-eight in number; capitulum with forty-eight radiating rows of small sessile, somewhat lobed and subdivided tubercles or papillæ, increasing in size to the margin, which is crenulate or dentate with the last tubercles of each series; the length of these rows of papillæ bears a relation to the corresponding tentacular cycle; the twenty-four small ones extend only about a quarter of the distance from the margin of the column to the bases of the third cycle of tentacles.

A. Bradleyi, Verrill, 1868, Trans. Connect. Acad. I. 1868, p. 465.

? **PHYLLODISCUS**, Kwietn.

Phyllactidæ, with a body-wall provided for the greater part with short, greatly branched processes, without a marginal fold. "Collar" high, with ectodermal musculature. Oral disc round, small. Tentacles long, numerous. Mesenteries numerous, only the primary mesenteries perfect, and at the same time sterile. Sphincter feeble, endodermal, diffuse or absent. Appendages of the body-wall with endodermal longitudinal muscles.

I have copied Kwietniewski's definition of his new genus ("Ein Beitrag zur Anat. und Syst. der Actiniarien," Inaug. Dissert., Jena. 1897, p. 11.), which he has erected for *P. Semoni*, a new species which he describes, but does not figure. It appears to me from Kwietniewski's description, that this genus should be placed in the Aliciidæ, but I will not venture to remove it, for the present, from the family to which he has allocated it. There are 192 tentacles, the mesenteries are in five cycles, of which the six pairs of primaries are alone perfect. The second, third, and fourth pairs of mesenteries are alone fertile.

Kwietniewski states his conviction (*l. c.*, p. 11) that *Triactis producta*, Klung., is allied to *P. Semoni*. Andres placed it in the Phymanthidæ, but Kwietniewski denies that it has anything to do with this family. It is very probably a larval form, and I think it is wiser to leave its systematic position an open question for the present.

Family.—DENDROMELIDÆ, McM.

Actiniinæ, with a pedal disk; tentacles simple, arranged in cycles; the upper part of the column, immediately below the margin, provided with dendritic processes (pseudo-tentacles).

McMurrich (1889, Journ. Morph., p. 31) instituted a new tribe (Dendromelinæ) with the above definition; later he degraded it to a family. The family (1893, p. 133; 1896, p. 186) contains the two very remarkable genera, Lebrunea, a shallow-water form from the West Indies, and Ophiodiscus, obtained by the "Challenger" from deep water (2160 and 1375 fathoms) in the Southern Pacific. The former has no sphincter; the latter, as described by Hertwig (1882, p. 56), has a mesoglœal sphincter, and has its mesenteries specialised into muscular and gonophoric cycles. Hertwig and McMurrich agree that these two genera may eventually have to be placed in different families.

McMurrich (*l.c.* p. 32) says:—"Duchassaing and Michelotti considered the genus Lebrunea to be close to Phyllactis, but such an alliance is unquestionably erroneous. The pseudo-tentacles [of Lebrunea] have no relationship either in position or structure to the fronds of the Phyllactidæ." As McMurrich has made a special study of these forms, and speaks so emphatically on this point, we must accept his position for the present. In a later paper (1896, p. 186) he says:—"With the two forms already mentioned, it seems that a third should be associated, namely, the *Hoplophoria coralligens* described by H. V. Wilson (1890), which, as I have already pointed out elsewhere (1893, p. 133), seems to be identical with the *Viatrix globulifera* described by Duchassaing and Michelotti (1860)." Until we have further information on these forms, I cannot accept this conclusion; and I suspect that Lebrunea itself will eventually be ranked under the Phyllactidæ. For the present, this family consists of two genera only—

Ophiodiscus, Hertw.
    O. annulatus, Hertw., 1882, p. 57.
    O. sulcatus, Hertw., 1882, p. 61.

Lebrunea, D. & M.
    L. neglecta, D. & M., 1860, p. 324; McM., 1889, p. 33; 1896, p. 186.

Family.—BUNODIDÆ, Gosse.

Actiniinæ adhering to foreign bodies by a flat contractile base; column usually provided with tubercles, or verrucæ; capitular margin often with acrorhagi, which may be complicated; no cinclides; sphincter muscle endodermal, strongly circumscribed; often numerous, perfect mesenteries, all of which may be gonophoric, but sometimes the directives are sterile; no acontia.

Only two members of this family are at present known from Torres Straits.

The following genera belong to this family:—

Bunodes.
Aulactinia.
Ixalactis.
Leiotealia.
Urticina (Tealia).
? Gyractis.

BUNODES, Gosse.

Bunodidæ, with the column provided with tubercles arranged in vertical series, of which either all reach the base, or only those corresponding to the primary tentacles, in which case the other series stop at varying distances from the margin according to their importance. Margin tuberculate and forming a more or less distinct collar. Tentacles polycyclic and entacmæous. At least twelve pairs of perfect mesenteries.

AULACTINIA, Verr.

"Bunodidæ, with the upper portion of the column provided with longitudinal rows of verrucæ, the lower portion being smooth. The margin forms a more or less distinct collar, and the tentacles are polycyclic and entacmæous. The six pairs of mesenteries of the first cycle are alone perfect (?)."

I have adopted McMurrich's (1889, Journ. Morph., p. 27) definition of this genus, but I have queried the last statement. I have no doubt that this is true of the type species, and it may be diagnostic of the genus; but rather than make a new genus of the Torres Straits species, I have ventured to include in Aulactinia a species which has more than six pairs of perfect mesenteries. Quite possibly the two species will subsequently be dissociated.

Externally Aulactinia differs from Bunodes, in having suckers in the upper portion of the column only, whereas the latter genus is more or less uniformly tuberculated; Leiotealia is quite smooth. The new genus, Ixalactis, is characterised by its peculiar tentacles, and in having the upper portion of the column verrucate and the lower smooth. Carlgren (1893, p. 58) confirms the observations of Gosse (1860, *Actin. Brit.*, p. 209), the brothers Dixon (Proc. R. D. S., 1889, p. 320, A. M. N. H., January, 1890, p. 66), and J. T. Cunningham (Journ. Mar. Biol. Assoc. 1889, p. 205), on the quinary symmetry of Urticina (Tealia); the column of this genus is verrucate. For the present I follow the general custom of leaving Urticina in the Bunodidæ.

Gyractis has a perfect sex-radial symmetry: it may not belong to this family.

Aulactinia Gelam (H. & S.).

Condylactis Gelam, Hadd. and Shackl., 1893, Proc. R. D. S. VIII., p. 123.

(Pl. XXII., fig. 12; Pl. XXVIII., figs. 6, 7.)

Form.—Column smooth, expanded at capitulum, which is furnished with suckers; disk feebly retractile; mouth circular, with two or three gonidial grooves; tentacles long, in six or seven cycles, from about 192 to 240 in number.

Colour.—Column red-lead colour below, passing into creamy yellow above; underside of capitulum grey, with pale suckers; (*a*) disk and tentacles olive brown; mouth green; tentacles with a greenish contour, and tipped with magenta; (*b*) disk grey; tentacles dark grey, with a buff sheen.

Dimensions.—Height of column, 150 mm. (6 in.); diameter, 44 mm. ($1\frac{3}{4}$ in.); diameter of oral disk, 95–115 mm. ($3\frac{3}{4}$–$4\frac{1}{2}$ in.); length of tentacles, 50 mm. (2 in.); diameter of corona, 180 mm. (7 in.).

Habitat.—On reefs, Mabuiag and Mer.

There is a slight difference in the transverse sections of the sphincter of the specimens from these two widely separated islands (over 100 miles apart), but I do not think it necessary to make distinct species of them. The well circumscribed muscle of the specimen from Mabuiag is shown on Pl. xxviii., fig. 6, and that of the specimen from Mer in fig. 7; the latter is about twice the size of the former, and both sides of the stem of the muscle are beset with mesoglœal plaits. There are numerous perfect mesenteries.

IXALACTIS* (n. g.).

Bunodidæ, with a pedal disk, soft body-wall, which is smooth below and verrucate above; tentacles very numerous, with alternately large and small transverse swellings on their oral surface; the tentacles are mainly disposed round the periphery of the oral disk, but some occur on the central zone of the disk; sphincter muscle circumscribed, endodermal.

Ixalactis simplex (H. & S.).

Phymanthus simplex, Hadd. and Shackl., 1893, Proc. R.D.S. viii., p. 123.

(Pl. XXV., figs. 15–19; Pl. XXVIII., figs. 8, 9.)

Column.—Soft, corrugated when contracted; lower portion smooth; upper portion with suckers, which are larger below, smaller above; parapet crenulated, the crenulations agreeing with the mesenterial chambers.

Disk.—Flat, when fully expanded, often thrown into half-a-dozen folds, never completely retractile (Pl. xxv., fig. 15). Mouth rounded; stomatodæum, with two œsophageal grooves, which are not very distinct.

Tentacles.—Of two kinds, centripetal and centrifugal:—(1) The inner tentacles are arranged in three cycles, and extend from about one-half to one-third of the radius of the disk, starting from the mouth; the inner cycles are about 48 in number. (2) The marginal tentacles are arranged in four or five cycles, and consist of probably about 192 tentacles (6 + 6 + 12 + 24 + 48 + 96 = 192). Aboral aspect of each tentacle rounded, smooth; oral aspect, flattened with symmetrical lateral swellings, which are alternately large and small, the former being some half dozen in number (Pl. xxv., figs. 17–19). The inner tentacles are slightly the larger. Tentacles irritable and contractile; when contracted

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* I have named this genus from the resemblance that the side view of a tentacle (Pl. iv., fig. 17) has to the horn of an Ibex, ἴξᾰλος: epithet of the Ibex; *cf.* Iliad iv. 105: *ἰξάλου αἰγὸς ἀγρίου.*

they have a decidedly beaded appearance, and resemble the figures of *Heteractis aurora*, Q. & G.

Colour.—Column cream below streaked with red-lead, blotched or spotted inferiorly; upper portion pale greenish or bluish grey; suckers and marginal crenulations white; disk, central area cream colour, with radial dark-brown lines, which divide into two after a definite plan, but in an irregular manner. There are 48 (?) splashes of a clearer ground colour on the disk between the lines which indicate the mesenteries of the inner series of tentacles; beyond them the colour is more dusky; the area of the inner series of tentacles is dark brown; a white spot in front of each of the inner series of tentacles passes round the base, and extends peripherally as two broad white bands. The two inner cycles of the inner series of tentacles have a distinctly madder tinge on their oral aspect, with a green sheen. Marginal tentacles transparent brown aborally, cream colour orally, the swollen portions spotted in the middle.

One specimen, with a greenish grey in the upper part of the column, had a disk of variegated greenish grey, darker towards the centre, paler peripherally, and with tentacles of a slightly darker ground colour, with nearly white protuberances on their oral aspect.

Dimensions.—Height about 100–130 mm. (4–5 inches); diameter of corona (*i.e.* disk + tentacles), 250 mm. (10 inches); largest tentacles, 30 mm. + 6 mm. ($1\frac{1}{8}$ in. + $\frac{1}{4}$ in.)

Habitat.—Surface of fringing reef, Mer.

Very probably this is the species referred to by Saville-Kent as CONDYLACTIS, sp. ("The Naturalist in Australia," 1893, p. 222, Pl. XXXIX A., fig. on p. 222), which he found in Western Australia.

At first I was inclined to connect this species with *Phymanthus muscosus*, but the former is one of the Stichodactylinæ, and has a diffuse endodermal sphincter, which is very different from the strongly circumscribed sphincter of the present species.

M^cMurrich has recently (1896, p. 184) discussed the genus Heteractis, and has shown that *H. lucida*, D. & M., is a Sagartid. I think Duchassaing and Michelotti were mistaken in placing their species in this genus, and M^cMurrich equally so in following them. Until *Ragactis pulchra* is anatomically investigated, "*H.*" *lucida* must remain without a genus.

I cannot be sure that my species does not belong to the genus Heteractis, but Quoy and Gaimard make no mention of suckers, so I think it best to keep them distinct for the present.

The possession of tentacles at the margin and towards the centre of the oral disk suggests that this species should be placed among the Stichodactylinæ, but I cannot satisfy myself that more than one tentacle springs from a mesenterial chamber.

The mesenteries, so far as I can make out, consist of 192 pairs, arranged in the usual symmetry of six. There are two gonidial grooves.

The position and character of the sphincter muscle are shown in Pl. XXVIII., figs. 8, 9. There is a long central stem of mesoglœa, with root-like branches along the greater part of its length on both sides.

LEIOTEALIA, Hertw.

Bunodidæ, with the column smooth, and without spherules, but with longitudinal furrows corresponding to the insertion of the mesenteries. Tentacles of equal size arranged in several cycles. Twelve pairs of perfect mesenteries. Body constricted by a special circular diffuse endodermal muscle.

URTICINA, Ehr. (Tealia, Gosse).

Bunodidæ, with the column provided with adhesive warts or suckers arranged in vertical series, suckers largest above. Capitular margin forming a parapet, separated from the tentacles by a broad fosse. Tentacles numerous, in decimal cycles, short or of moderate length and of uniform size. At least twenty pairs of perfect mesenteries.

GYRACTIS, Bov.

Bunodidæ (?), with a perfect radial symmetry, all the pairs of mesenteries have their longitudinal muscles on the sides facing one another, *i.e.*, in the endocœls; new mesenteries are developed in the exocœls. Mouth circular, no siphonoglyphes present. Circumscribed endodermal sphincter muscle.

E. excavata, Bov. *E. pallida*, Bov.

Boveri (Das Genus Gyractis, eine radial-symmetrische Actinienform, Zool. Jahresbr., vii., 1893, p. 241) proposes the tribe Holactiniæ for the reception of this new Sinhalese genus. As the variability, and even the absence of directives in various groups or genera of Actiniaria is now being recognised, it is doubtful how far it is wise to make this a primary character. As previously mentioned, Carlgren describes a specimen of *Sargatia undata*, with a complete symmetry of 8, in which there were no directives. On the whole I feel inclined to agree with McMurrich ("Contributions to the Morph. of the Actinozoa: IV. On some irregularities in the number of the directive mesenteries in the Hexactiniæ." Zool. Bul., Boston, I., 1897, p. 115), that this genus should be placed among the Bunodidæ.

Family.—PARACTIDÆ, Hertw.

Actiniinæ with a pedal disk, a smooth or warty column; no cinclides; tentacles short and stout to moderately long; usually numerous perfect mesenteries; acontia wanting; strong mesoglœal sphincter muscle.

As this family is not represented in my collection I shall say very little about it. It was erected by Hertwig (1882, p. 41), and has been established by Simon (1892, p. 45), and M^cMurrich (1893, p. 160). Carlgren proposes (1893, p. 137) to separate from it a new family Actinostolidæ. Both families agree in having a pedal disc, moderately long tentacles, and numerous perfect mesenteries; radial musculature of the oral disk, and longitudinal muscles of the tentacles usually mesoglœal; sphincter mesoglœal generally well developed. Acontia and cinclides wanting. In the Paractidæ the mesenteries are all "regularly developed," whereas in the Actinostolidæ "the pairs of mesenteries of the higher cycles (from the third and fourth on) irregularly developed, so that the mesentery whose longitudinal muscle generally looks towards the next lower mesentery cycle is more developed than the other of the same pair." Perhaps it would be better to make these two groups into sub-families.

The genera Paractis, M. Edw.; Paranthus, Andr.; Anthosactis, Danl.; Stomphia, Gosse; Dysactis, M. Edw.; Ophiodiscus, Hertw. (?);* Tealidium, Hertw.; Antholoba, Hertw.; Actinernus, Verr. (Polysiphonia, Hertw.); Actinostola, Verr; Pycnanthus, M^cM.; Cymbactis, M^cM.; Kadosactis, Danl.; and Kyathactis, Danl., have been placed in this family by various authors.

Family.—SAGARTIIDÆ, Gosse.

Actiniinæ with a contractile pedal disk; body-wall smooth, or provided with verrucæ or tubercles, and usually perforated by cinclides, with or without a cuticle. Tentacles usually numerous and retractile, not very long, smooth, simple, and generally entacmæous. Sphincter muscle characteristically well developed and mesoglœal, occasionally diffuse endodermal, or even absent. At least six pairs of perfect mesenteries; the first cycle of six pairs of mesenteries may be fertile or sterile. Acontia present.

This family was erected by Gosse in 1858 (Ann. Mag. Nat. Hist. (3) I. p. 415); I partially discussed the family, and described a new sub-family in 1889 (Trans. R. D. S. (2) IV. pp. 301 *et seq.*; Simon (1892); Carlgren (1893, p. 86); and Kwietniewsky (1897, p. 323) have more recently discussed the limits of this

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* M^cMurrich regards this as one of the Dendromelidæ.

family; so there is no reason why I should enter into a tedious disquisition on the subject.

Simon ("Beitrag zur Anat. und Syst. der Hexactinien," Dissertation, München, 1892) recognizes two sub-families:

AIPTASIINÆ, with an endodermal sphincter, or none at all.

SAGARTIINÆ, with a strong mesoglœal sphincter; among the latter he distinguishes between the Sagartians without, and the Phellians with, a cuticle.

Carlgren divides the family into three sub-families:

SAGARTIINÆ, with the genera Sagartia, Cylista, Gephyra, and Cereus.

METRIDIINÆ, with Adamsia, Metridium, Aiptasia, Stelidiactis, and Calliactis.

PHELLIINÆ, with Chondractinia, Hormathia, Chitonactis, Actinauge, Phellia, and Kodioides (?).

Kwietniewski does not give a classification, but he adopts the Phelliinæ, and accepts M^cMurrich's (1889) definition: "Sagartiidæ, with a cuticular covering to a body-wall."

It appears to me that at present we may adopt some such arrangement as follows:

AIPTASIINÆ. PHELLIINÆ.
SAGARTIINÆ. METRIDIINÆ.
CHONDRACTINIINÆ.

Of these five sub-families, the first is sharply separated by the character of the sphincter muscle from the remaining four, which constitute a group by themselves.

Sub-Family.—AIPTASIINÆ, Simon.

Sagartiidæ, in which the sphincter muscle is either absent or very feebly developed and mesoglœal, or diffuse and endodermal.

Aiptasia, Gosse, 1860.

Aiptasiinæ, with an extensile soft body, cinclides arranged in from one to several horizontal rows around the middle of the column; no verrucæ or tubercles; tentacles strongly entacmæous; sphincter muscle either absent or very feebly developed and mesoglœal, or diffuse and endodermal.

M^cMurrich states, that there is no trace of any sphincter muscle in *Aiptasia* *annulata* or *A. tagetes*, both of which species he has studied; and the same is the case with *A. diaphana* according to Hertwig (1879); but McMurrich informs us (1889, Journ. Morph., p. 6, footnote) he has found in *A. pallida*, "a slightly developed muscle imbedded in the mesoglœa." Simon (1892, p. 69) describes the sphincter muscle of *A. mutabilis* as being of the diffuse endodermal type, such as is characteristic, for example, of the genera Actinia and Anemonia, but he gives no figure. He goes on to say: "McMurrich hat bei einem seiner Exemplare von *A. annulata* ebenfalls Anzeichen eines schwachen diffusen Ringmuskels beobachtet"; whereas the latter twice states that no signs of a sphincter muscle were observed.

In *A. mutabilis*, according to Simon's observations, there is a generalised sphincter, the absence of a sphincter in *A. annulata* and *A. tagetes* may be regarded as due to degeneration, and not as being a primitive character; this view is supported by the slightly developed muscle in the mesoglœa in *A. pallida*, since an incipient sphincter is always endodermal. The presence of acontia and cinclides also proves that these are specialised forms.

The type species, *A. Couchii*, has not yet been investigated; but as Gosse (1860, p. 154) says the generic appellation refers to "its permanent expansion"; and as he also alludes to "the patience with which it bore pushings, and pokings," we may safely conclude that, if it has a sphincter muscle, it is very feebly developed, and is probably practically functionless.

The mesenteries are in multiples of four (*A. annulata*), or of six. The first cycle of four or six pairs of mesenteries alone are perfect and are usually sterile, though in *A. pallida* and *A. sp.* (McMurrich, Proc. Acad. N. Sci. Phila., 1889, p. 103), the mesenteries of the first cycle, with the exception of the directives are fertile.

The following species may be placed under this genus, but it must be remembered that only the four species have been anatomically examined.

A. Couchii, Cocks; *A. lacerata*, Dal. (*fide* Andres, 1884, p. 159--but I am by no means sure of this identification; the form, I think, is *A. lacerata*, Dal.—one of the Sagartinæ. If this be so, Andres' earlier name, *A. comata*, Andr., 1880, must be adopted for the Neapolitan species, as *A. hyalina*, D.Ch., was pre-occupied); *A. carnea*, Andr.; *A. mutabilis*, Grav.; *A. saxicola*, Andr.; *A. diaphana*, Rapp.; *A. annulata*, Les. (=*A. solifera*, Les.: *cf.* McMurrich, 1889, Journ. Morph., p. 7); *A. tagetes*, D. & M.; *A. pallida*, Verr. (= *A. Agassizii*, *n. n.*, Andr.).

Sub-Family.—SAGARTIINÆ, Verrill.

Sagartiidæ, with more than six pairs of perfect mesenteries, of which the six pairs of primary mesenteries are fertile, except the directives in some species; body wall soft; no tubercles, but verrucæ (suckers) may be present in the upper part of the column; cinclides present (chiefly ectodermal invaginations); one or two gonidial grooves; strong mesoglœal sphincter muscle.

The following genera have been placed in this sub-family:—
Sagartia, Cylista, Gephyra, Cereus (Heliactis), Nemactis.

SAGARTIA, Gosse.

Sagartiinæ with a smooth body-wall, or with small verrucæ, in the upper portion of the column; moderately long tentacles in several cycles around the margin of the oral disk, which is not greatly expanded.

Carlgren does not distinguish between the genera Sagartia aud Cylista as he finds the presence or absence of suckers to be variable.

Sagartia Milmani (H. & S.).

Thoe (?) *Milmani*, Hadd. and Shackl., 1893; Proc. R.D.S. VIII. p. 130.

(Plate XXIII., fig. 16; Plate XXIX., figs. 1–5.)

Form.—Body soft; large pedal disk; oral disk not greatly exceeding diameter of column; tentacles, moderately short, numerous, in four or five cycles; mouth oval.

Colour.—Column of a smoky yellow colour, sparsely speckled with dark brown; tentacles pale lemon yellow below, with a central, broad, ash coloured band, and translucent white above.

Dimensions.—Diameter of corona, 30 mm.

Habitat.—Albany Pass, Cape York, 10 fathoms.

The mesoglœa is not very thick, but it is sufficiently firm to prevent the body from collapsing when preserved in alcohol. The ectoderm and endoderm are thin; the latter does not contain zooxanthellæ. The ectodermal and endodermal musculature of the oral disk is well developed; the mesoglœal plaits of the former being especially so, and are long and branched.

The sphincter muscle (Pl. XXIX., fig. 1) is very long, and for the greater part of its length consists of but few muscle-cavities (Pl. XXIX., figs. 3, 4), but superiorly (distally) there is quite a cluster of cavities (Pl. XXIX., fig. 2).

The mesenteries of the specimen examined consist of two pairs of directives, and four pairs of perfect mesenteries on one side, and six on the other; in each exocœl, there is one central pair of moderately developed, imperfect mesenteries, on each side of which is a pair of much smaller ones; the total number of mesenteries being 48 (12 + 12 + 24); but a sexradiate symmetry is not maintained.

The retractor muscle of the mesenteries is on the whole very feeble; but towards its distal end (*i.e.* near the mesenterial filament) it forms a small protuberance (Pl. XXIX., fig. 5). The parieto-basilar muscle is very feeble, only a few small plaits could be discerned on the side of the mesentery bearing the retractor muscle.

There were no gonads in the specimen that was sectionised.

An irregularity in the number of the perfect mesenteries is characteristic of the genus Sagartia.

Dr. Carlgren (1893, pp. 98, 99) finds in the typical variety of *Sagartia undata* (O. F. Müll.) that a hexamerous arrangement of the mesenteries is by no means adhered to, and also, as occurs in other species of Sagartia, only one pair of directive mesenteries may be present, instead of the normal two pairs; the first, second, and even the third cycles of mesenteries may be perfect. In one specimen, with one pair of directives, Carlgren found the formula for the pairs of mesenteries as follows 5 + 5 + 10 + 20 + 40, and in another 8 + 8 + 16. Other irregularities were observed. In one specimen, with mesenteries arranged in a symmetry of 8, there were no directives present, and the animal was completely radial. Two examples were met with having three directives, in another (var. *undata* β) were eleven perfect and eleven imperfect pairs of mesenteries. The arrangement of the mesenteries in one specimen was as follows (*D* . 5 . *D* . 3 . *D* . 3) + 14 + 28, and in another (*D* . 5 . *D* . 6) + 13 + 26; that is, in the former there were three directives separated, respectively, by five, three, and three pairs of mesenteries all of which were perfect, the remaining cycles were imperfect; and in the latter thirteen pairs of mesenteries were perfect, including the two directives. One young specimen of var. *undata* α, had precisely the condition which occurs in the adult Gonactinia (cf. Trans. R. D. S. IV., 1889, pp. 341, 354).

Still more recently, McMurrich (Zool. Bulletin, Boston, I., 1897, p. 117) describes the following irregularities in seven specimens of *Sagartia spongicola*, Verr. Two are arranged on the hexamerous plan, two on a heptamerous plan, and three on an octamerous; in one specimen there are two pairs of directives (which are not opposite each other), in five there are three pairs, and in one specimen four pairs of directives.

Sagartia Plebeia, n. sp.

(Pl. XXIII., fig. 17; Pl. XXIX., fig. 12).

Form.—Column smooth, soft, columnar; oral disk, of about same diameter as column or slightly wider; tentacles probably in four cycles, simple, conical, about same length as diameter of oral disk; oral disk raised to a central cone; mouth linear, one oral groove. Acontia are emitted through lateral or basi-lateral cinclides which are not evident.

Colour.—Column reddish buff, with thin, vertical, pale, and dark streaks; tentacles umber-brown, with a few irregular cream-coloured spots, usually with an irregular band of white spots at base; oral disk translucent; the gonidial radius nearly white, a white line round the mouth; œsophagus reddish buff.

Dimensions.—Height of column, about 25 mm. (1 in.); diameter, 10 mm.; diameter of corona, about 45 mm. (1¾ in.).

Habitat.—Reef, Murray Islands.

Owing to an unfortunate mistake only vertical sections were made of the single specimen obtained. The sphincter muscle (Pl. xxix., fig. 12) is strong and comparatively short, its distal portion forms a prominent external swelling in the sections.

GEPHYRA, Koch.

Sagartiinæ with an expanded pedal disk that clasps zoophytes; the diameter of the disk considerably exceeds that of the column; tentacles not very numerous, and moderately short.

G Dohrnii, Koch.

CEREUS, Oken. (Heliactis, Thompson).

"Column very changeable in form, capable of becoming tall, pillar-like, or contracting to a low, depressed cone; no submarginal fold; upper part with small inconspicuous, contractile suckers; walls nearly smooth, pierced by scattered, inconspicuous pores or cinclidæ. Disc broadly expanded, wider than the column, sometimes undulated at the margin. Tentacles numerous, more or less scattered on the disk, usually rather stout, the inner ones considerably largest; the outer ones quite small. Type *C. bellis*" (Verrill, 1869, p. 480).

Verrill (Trans. Connect. Acad. I. 1869, p. 480) correctly restores Oken's genus. Thompson (P. Z. S. xxvi., 1858, p. 145; and A. M. N. H. (3), ii., 1858, p. 229) erected a new genus, Heliactis, which must lapse; and his identification of the genus Cereus (*l. c.* p. 232) is mistaken, as also is Hertwig's (Chall. Rept. I., 1882, p. 76). Gosse's proposed name Scyphia similarly disappears (Act. Brit. 1860, p. 123). For further synonymy, see Andres, pp. 137, 138.

C. pedunculatus (Penn.) [= *Sagartia bellis* (Ell. and Sol.) auct.]; *C. Paumotensis* (Dana); *C. Fuegiensis*, Verr.

NEMACTIS, M. Edw.

"Margin of the disk, outside of the bases of the tentacles, surrounded by a single circle of bright coloured, rounded tubercles. Acontia long and slender, protruded from the mouth, and *perhaps* from lateral pores."

I have quoted Verrill's diagnosis of this genus (Trans. Connect. Acad. I. 1869, p. 487). The most important character appears to be the presence of acrorhagi. M. Edwards' (1857, p. 282) definition is: "Pores situés près du bord du disque; des tubercules calicinaux." Verrill places under this genus the following species. *N. primula* (Drayt. in Dana); *N. Draytonia*, M. Edw.; *N.* (?) *Chilensis* (Less.).

Sub-Family.—PHELLIINÆ, Verrill.

Sagartiidæ with usually an elongated column, the capitular portion of which is generally delicate and extensile; body-wall provided with a cuticle, but without any solid or hollow processes, such as tubercles, vesicles, or suckers; no cinclides. Tentacles simple, neither very numerous nor very long. Only six pairs of perfect mesenteries which alone are fertile. The remaining mesenteries are usually feebly developed. The retractor muscles are very strongly developed on the primary mesenteries. Acontia usually feebly developed, and emitted only through the mouth. Strong mesoglœal sphincter muscle.

I have recently* stated that I consider the presence of gonads on the six pairs of primary mesenteries in Phellia, and their absence in the Chondractiniinæ to be of sufficient importance to place that genus in a distinct sub-family for which Verrill's (1868) name "Phellinæ" may appropriately be retained. Kwietniewski considers the Chondractiniinæ as a synonym of the Phelliinæ, which he defines as:—"Sagartians with a cuticular covering to the body-wall." This definition is not very explicit, and ignores the internal anatomy.

Octophellia, Andres (1884), has not yet been studied anatomically, nor can any other genus than Phellia be relegated with certainty to this sub-family. Simon's Phelliactis belongs to Chondractiniinæ.

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* "*Phellia Sollasi* a new species of Actiniarian from Oceania." Proc. Roy. Dubl. Soc. (N. S.), VIII., 1898, p. 701.

PHELLIA, Gosse.

With the characters of the sub-family.

The following members of the genus Phellia have been investigated anatomically. *P. limicola*, Andr. (Le Attiniæ, 1884, pp. 73, 74); *P. Ternatana*, Kwietn. Zool. Anz., 1896, No. 512, and Abhandl. Senckenbergischen naturf. Gesellsch., xxiii., 1897, p. 328; he also alludes, p. 327, to *P. Ambonensis*, and *P. decora* (?), Klunz., from Ambon and the Red Sea, respectively. *P. Sollasi*, Hadd., from Funafuti, Ellice group, has been described anatomically by Maguire (Proc. R. Dubl. Soc. VIII., Part VI., 1898, p. 717), and I have also studied *P. vermiformis*, n. sp., and a species of Phellia from Gare Loch, Scotland, which is probably *P. gausapata*, Gosse.

Andres gives a long list of species which have been described as belonging to this genus; to these must be added eight new species named by Danielssen (Actiniidæ, Norske Nordhavs-Exped., 1876–78 (1890)).

As the genus Phellia was instituted by Gosse in 1858 (Ann. Mag. Nat. Hist. (3) II., p. 192) for two new species of sea-anemones, *P. murocincta*, and *P. gausapata*, it is important to determine the anatomical characters of these species. Dr. John Murray entrusted to me a form that he obtained from low water near the head of Gare Loch on the Clyde. The length of the specimen when contracted and preserved in alcohol was 12 mm. long, and 7 mm. in diameter. The body was transversely wrinkled, and the upper third was thickly covered with cuticular scabs, these were thinly scattered elsewhere. It is always a difficult matter to determine the species of an Actiniarian from a single preserved specimen, but I have very little doubt that this is *P. gausapata*, Gosse (*cf.* Hist. of Brit. Sea Anemones, 1860, p. 140).

So far as the general anatomy is concerned this species agrees with the above-mentioned forms, and therefore we may safely regard them as belonging to the genus Phellia. The main point of difference is that, in *P. gausapata* there are in my sections only one pair of imperfect mesenteries in each of the exocœls, that is, there are only 12 pairs of mesenteries altogether. The form and pattern of the transverse sections of the retractor muscle also differs in details from that of the other species.

The only point calling for special notice is the number and disposition of the imperfect mesenteries. In *P. Ternatana*, and *P. vermiformis*, the arrangement in each sextant is as follows:—P ıı ˌˌ ‖ ˌˌ ıı P, that is, next to each pair of perfect mesenteries is a pair of small imperfect ones; then follow a minute pair (Pl. XXVIII., fig. 11), and in the centre of the exocœl is a pair of moderately large imperfect mesenteries. The same arrangement appears to be characteristic of the small specimen of *P. Sollasi* described by Dr. Maguire. But in one sextant, one- and in another two-pairs of mesenteries of the fourth cycle are present; those in fact that are missing is the more typical arrangement. In the large specimen of *P. Sollasi* there is more irregularity in some exocœls; the order is ıı ‖ ıı, while in others a variable number of fourth-cycle mesenteries make their appearance.

Phellia vermiformis, n. sp.

(Pl. XXIII., fig. 18; Pl. XXVIII., figs. 10, 11.)

Form.—Body elongated, worm-like, no distinct pedal disk; capitulum rather short; tentacles in 3 or 4 cycles, short, blunt, entacmæal, mouth linear. The acontia are few, and are feebly emitted from the mouth.

Colour.—Body pink, yellowish above; capitulum and tentacles greyish.

Dimensions.—Length of preserved specimen, 95 mm. (3¾ in.); diameter of capitulum, 12 mm.

Habitat.—Burrows in the sand, leaving only a short length of the upper part of the column exposed when expanded. Surface of reef, Thursday Island.

The appearance of the species when preserved in alcohol is shown in Pl. XXIII., fig. 18; in this figure the pedal disk is much more prominent than when alive.

Body-wall.—The ectoderm has a definite cuticle; the mesoglœa is thick and homogeneous. The mesoglœa of the œsophagus is also thick; there are two œsophageal grooves.

Sphincter.—The sphincter muscle (Pl. XXVIII., fig. 10) is long and mesoglœal, and lies close to the endoderm. It consists of a band of uniform width, broken transversely by numerous narrow strands of mesoglœa at irregular intervals. Throughout the region of the sphincter the endoderm of the body-wall is provided with strong muscular process, supported on slightly branched outgrowths of the mesoglœa.

Mesenteries.—The arrangement of the mesenteries has already been described. The formula is $6 + 6 + 12 + 12 = 36$. There is an exceedingly strong retractor muscle, the form of which varies in section; sometimes it is kidney-shaped, but fig. 11, Pl. XXVIII, is very typical.

Phellia sipunculoides, H. & S.

Phellia sipunculoides, Hadd. and Shackl. 1893; Proc. R. D. S. VIII., p. 128.

(Pl. XXIII., figs. 19, 20).

Form.—Body, columnar; pedal disk, flat, adherent; scapus, coriaceous, tesselated; capitulum, extensile, delicate; tentacles of moderate length and thickness, somewhat longer than diameter of oral disk, inner cycle longer than the outer; oral disk, circular; mouth, oval, on a cone.

Colour.—Scapus, grayish drab, of the same colour as the coral which it inhabits; capitulum, translucent, madder brown, with a white mark below each tentacle; tentacle and disk, olive brown, with a longitudinal white streak along their oral aspect, which is continued across the disk to the mouth.

Dimensions.—Length, when extended, 20 mm.; diameter of column, 12 mm.

Habitat.—In crevices of indurated dead coral rock, between tides; Cockburn Reef; N. Queensland.

The specific name is given to this form, on account of its resemblance when retracted to a contracted *Sipunculus nudus.*

Phellia Devisi, H. & S.

Phellia Devisi, Hadd. and Shackl. 1893; Proc. R. D. S. VII., p. 129.

(Pl. XXIII., figs. 21–24).

Form.—Body short, stout, columnar; pedal disk flat, adherent; scapus coriaceous, corrugated; capitulum delicate; tentacles short, with a swollen base, of about the same length as the diameter of the disk, inner cycles the longer; oral disk circular; mouth oval, no gonidial grooves apparent.

Colour.—Scapus buff; capitulum translucent madder violet, with a ring of small white marks; tentacles cream, with an interrupted dark line on oral aspect, base dark brown, edged with bright deep green, the outer cycle without colour on base; oral disk chestnut colour; lips dark brown; stomatodæum cream colour.

Dimensions.—Height and diameter of column, about 7 mm.

Habitat.—Crevices of indurated dead coral rock, between tides, Cockburn Reef; N. Queensland.

Unfortunately the specimens of these last two species were lost, and so no anatomical investigation of them could be made. There is little doubt that they belong to this sub-family.

Sub-Family.—METRIDIINÆ, Carlgr.

Sagartiidæ with six or more pairs of perfect mesenteries, of which the six pairs of primary mesenteries are sterile; usually one gonidial groove with its pair of directives, but more may occur; body-wall relatively thin, and without a cuticle; cinclides present (chiefly endodermal evaginations); well developed mesoglœal sphincter muscle.

I have only slightly modified Carlgren's definition of this sub-family. He included in it Metridium, Adamsia, Calliactis, Stelidiactis, and Aiptasia, and thinks that Paraphellia should be placed here too. The genus Aiptasia must be separated from it, as it constitutes the type of a sub-family of Sagartids; and the genus Mitactis, Hadd. and Duerd., should be added to it, and I regard the genus Paraphellia as belonging to the next sub-family.

METRIDIUM, Oken (Actinoloba, Blainv.).

Metridiinæ with a smooth body-wall and numerous tentacles, which extend over nearly the whole of the oral disk, which is greatly expanded and frilled; the upper border of the column is swollen to form a thickened ring, above which is the delicate capitulum.

M. dianthus (Ellis), *M. marginatum* (Les.), *M. fimbriatum* (Verr.), *M. reticulatum* (Dana).

MITACTIS, Hadd. and Duerd.*

Metridiinæ with a smooth body-wall; oral disk of not much greater diameter than the column; tentacles short, marginal in three or four cycles.

M. Australiæ, H. & D.; *M. similis*, H. & D.

ADAMSIA, Forbes.

Metridiidæ, with cinclides arranged in from one to several horizontal rows towards the base of the column; no verrucæ; column short, base extended into two broad lateral lobes, clasping a gastropod shell inhabited by a hermit crab, the lobes unite where they come in contact, giving the body an annular form; the pedal disk secretes a tough cuticle; tentacles short.

This genus was erected by Forbes (Ann. Mag. Nat. Hist. v., 1840, p. 181) for *A. palliata*, Boh. (or *A. maculata*, Adams, as he called it).

CALLIACTIS, Verr.

Metridiidæ, with prominent cinclides, arranged in from one to several horizontal rows towards the base of the column; no verrucæ; column very changeable in form, in full expansion elevated, sub-cylindrical, with a broadly expanded base, in contraction forming a low, flattened cone or convex disk; basal margin

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* Trans. R. D. S. (2), vi., 1896, p. 162.

below the cinclides thin and expanded, usually with additional internal mesenteries intercalated between the larger ones; tentacles numerous, slender, subulate, highly contractile. Acontia highly developed, emitted freely through the cinclides.

This definition is based mainly on that of Verrill, who instituted this genus for Actiniaria, which are allied to Adamsia, but which have a higher column and less expanded base; the tentacles also are longer. The type species is *C. decorata* (Drayt.). This genus appears to be abundant in the tropical seas, the species usually living upon univalve shells inhabited by hermit-crabs. The colours are usually brilliant and varied.

C. decorata (Drayt.), *C. tricolor* (Les.), *C. bicolor* (Les.), *C. Egletes* (D. & M.), *C. fusca* (Q. & G.), *C.? polypus* (Forsk.), *C. variegata* (Verr.), *C. Rondeletii* (D.Ch.) (= *A. effœta* and *A. parasitica*, Auct.), *C. Miriam* (H. & S.).

Calliactis Miriam (H. & S.).

Adamsia Miriam, Hadd. and Shackl., 1893, Proc. R.D.S., VIII., p. 130.

(Pl. XXIII., fig. 25.)

Form.—Pedal disk greatly expanded; body columnar, smooth, twenty-four cinclides where the column passes into the pedal disk; oral disk of scarcely greater diameter than column, completely retractile; mouth linear, two gonidial grooves; tentacles numerous, short, in at least five cycles.

Colour.—Base pale, with six large and six smaller brown patches, the spaces between with delicate brown lines; cinclides yellowish white; column reddish brown; the crown of tentacles is mottled with six radial patches of dark brown, in each of which all the tentacles have the same colour, whereas in the lighter patches the tentacles are translucent pale brown, the upper part being banded with brown and white on their oral aspects.

Dimensions.—Diameter of basal disk about 44 mm.; height of column, 28 mm.; average diameter of column, 18 mm.

Habitat.—Shell of *Dolium*, inhabited by a hermit crab; from surface of reef, Mer.

The salmon-coloured acontia were emitted chiefly through the basal cinclides, but also from the mouth.

This species is allied to *Adamsia decorata.*

Unfortunately the single specimen of this species was lost, but there is no doubt as to its generic name.

STELIDIACTIS, Danl.

Sagartids with a soft body-wall and a clasping base that secretes a cuticle; the cinclides occur irregularly about the middle of the column, at the bottom of twenty-four longitudinal grooves; oral disk of about the same diameter as the column; tentacles 24 or 48 short, conical completely retractile; six pairs of sterile perfect mesenteries, the other large mesenteries are fertile.

This definition is compiled from Danielssen's account of his two species, *S. Mopsiæ* and *S. Tubulariæ*. It is not satisfactory to criticise forms of which one has no acquaintance, but I suspect that these two are merely varieties of the same species, which externally resembles *Gephyra Dohrnii*, von Koch. I have previously (Trans. R.D.S. (2), IV., 1889, p. 325) recorded the latter species from the south-west of Ireland.

Sub-Family.—CHONDRACTINIINÆ, Hadd.

Sagartiidæ with only six pairs of perfect mesenteries, which alone of the well-developed mesenteries are sterile; two gonidial grooves and two pairs of directives, body-wall usually thick, with a cuticle and often nodulated; cinclides absent(?); acontia rarely emitted, and then by the mouth only; strong mesoglœal sphincter muscle.

In this sub-family I originally (1889, p. 305) included the genera Chondractinia, Hormathia, Chitonactis, Actinauge, and Paraphellia. Simon, Carlgren, and Kwietniewski believed that Phellia belongs to this group, and so have restored the older term Phelliinæ. As Phellia has its primary cycle of mesenteries alone fertile, we must remove it from the other forms, and so my name stands.

SYNOPSIS OF THE GENERA.

	Capitulum.	*Scapus.*	*Tentacles.*	
Actinauge, ...	ridged.	tuberculate.	basal swellings.	
Hormathia, ...	smooth.	,,	no basal swellings.	
Chitonanthus, ...	ridged.	,,	,, ,,	
Paraphellia, ...	smooth.	smooth.	,, ,,	
?Stephanactis, ...	,,	,,	,, ,,	clasping base.
Phelliactis, ...	,,	,,	basal swellings.	
?Ammonactis, ...	,,	,,	,, ,,	elongated.

ACTINAUGE, Verr.

Chondractiniinæ, in which the capitulum is provided with longitudinal ridges; scapus strongly tuberculate or nodulate, the tubercles near the junction of the scapus and capitulum being usually stronger than those lower down; each tentacle with a bulbous thickening on the outer surface at the base.

I have adopted McMurrich's (1893, p. 183) emendation of the diagnosis of this genus.

A. Verrillii, McM. (*n. n.* for *A. nodosa*, Verr., *A. sp.* Hadd. *cf.* McM., 1893, p. 184); *A. fastigata*, McM. (*n. n.* for *A. nodosa*, var. *coronata*, Verr.); *A. Richardi*, Mar. (*cf.* Haddon, Trans. R. D. S., 1889, p. 319).

HORMATHIA, Gosse.

Chondractiniinæ, inwhich the capitulum is smooth and the scapus is tuberculate; no bulbous enlargements at the bases of the tentacles.

McMurrich, in the Appendix to his Report on the Actiniæ collected on the cruise of the "Albatross" (Proc. U. S. Nat. Mus., xvi., 1893), suggests that it will prove necessary to fuse the genera Chondractinia, Chitonactis, and Hormathia into one as the characters which have been employed to distinguish these genera are by no means well defined. I am inclined to think that this is a legitimate position to take and so I have adopted this innovation. I also agree with him, in removing *Phellia pectinata*, Hert., and *H. Andersoni*, Hadd., to the genus Chitonanthus. *Hormathia delicatula*, Hert. (1888, p. 15), with its diffuse endodermal sphincter, marginal spherules, and three cycles of perfect fertile mesenteries probably belongs to the genus Actinia.

H. Margaritæ, Gosse (*cf.* Haddon, Trans. R.D.S. 1889, p. 310); *H. digitata*, (O. F. Müll)* (*cf.* Haddon, *l.c.* p. 306), *H. nodosa* (Fabr.)* (*l.c.* p. 308); *H. coronata*, Gosse (*l.c.* p. 312); *H. Marioni* (Hadd.) (*l.c.* p. 313); *H. longicornis* (Verr.); *H. spinosa*, (Hert.) (= *Cereus spinosus*, Hert., 1882, p. 76, *cf.* T. R.D.S. 1889, p. 315); *H. minuta*, (Hert.) (= *Bunodus minuta*, Hert., 1882, p. 84: *cf.* Trans. R.D.S., 1889, p. 315).

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* These two species, under the genus Chondractinia, have been carefully investigated anatomically by Carlgren (Kongl. Svenska Vet.-Akad. Handl. xxv., 1893, pp, 110, 115).

CHITONANTHUS, McM.

Chondractiniinæ, in which the capitulum is provided with longitudinal ridges; the scapus, especially in its upper portion, with strong pointed tubercles, not arranged in any definite order, or else with a single circle of coronal tubercles; the cuticle strongly developed upon the tubercles; tentacles without any bulbous enlargement at the base.

This new genus has been erected by McMurrich (1893, p. 189, for *Phellia pectinata*, Hert., 1882, p. 81; *cf.* McMurrich, Proc. U. S. Nat. Mus., 1893, p 190 (= *Phellia spinifera*, Hert., 1888, p. 24), and *Hormathia Andersoni*, Hadd. (Journ. Linn. Soc. 1888, p. 251).

C. pectinata (Hert.); *C. Andersoni* (Hadd.).

PARAPHELLIA, Hadd.

Chondractiniinæ, with a smooth capitulum and scapus; the cuticle is not developed; a thin mesoglœa; sphincter relatively small.

This genus was instituted (Trans. R.D.S., 1891, p. 321) for a new species from the south-west of Ireland; since then, I have come across two species which appear to me to belong to this genus.

I find that Verrill ("Synopsis of the Polyps and Corals of the North Pacific Exploring Expedition," Proc. Essex Instit., Salem, 1867 (1868), v., p. 326) suggests that the form he describes as *Phellia inequalis*, Verr., n. sp., may be the type of a new genus. "Should this be thought desirable," he adds, "I would suggest the name Paraphellia. The principal structural peculiarities are the extremely short, knotted, outer tentacles; the very narrow, submarginal, naked zone; the firm, inseparable epidermis, and the papillose appearance of the upper part in contraction. The last two characters are also found in *P. gausapata*, Gosse." The specimen came from Bonin Island. The tentacles are about forty in number, the twenty internal ones are considerably longer than the twenty that compose the outer row, the latter are very short and have three constrictions. I must leave it to other zoologists to decide whether Verrill's proposed name takes precedence of mine. We have no proof that Verrill's form is a Sagartid, he states "no acontia or loop-holes observable."

P. expansa, Hadd. (Proc. R. I. Acad. (2), iv. Sci. 1886, p. 616); *P. Hunti*, H. & S.; *P. lineata*, H. & S.

Paraphellia Hunti, H. & S.

Paraphellia Hunti, Hadd. and Shackl., 1893, Proc. R.D.S., VIII. p. 129.

(Pl. XXIII., fig. 26; Pl. XXIX., figs. 6–9.)

Form.—Body columnar, very contractile, when fully contracted like a scab; oral disk but little exceeding the diameter of the column; tentacles short in four cycles (6 + 6 + 12 + 24); mouth with two gonidial grooves.

Colour.—Column mealy pink, with twelve longitudinal grey bands—of which six are broader, and six narrower, tentacles whitish with pale grey bands; oral disk tawny orange along sides of mouth, remainder variously pencilled with white, dark grey, and black, often a series of black spots up some of the white radii; mouth with five dark spots at each side, and a white one at each end; œsophagus creamy orange.

Dimensions.—Height of column about 10 mm., average diameter 8 mm.

Habitat.—Passage between reefs, Murray Islands; 15 fathoms.

Tentacles.—The ectoderm of the tentacles is very thick, and transversely wrinkled: the nematocysts form a distinct outer layer; then follows a thick granular or nucleated layer; below this is a clear layer; and finally the muscular layer, supported by well-developed plaits of the mesoglœa. The mesoglœa is moderately thick. The endoderm is not so thick as the ectoderm, and is without zooxanthellæ; the endodermal muscular layer is supported on simple mesoglœal processes. The structure of the disk is similar to that of the tentacles.

Column.—The ectoderm is very thin, and contains dark-brown granules. The mesoglœa is moderately developed. The endoderm has no zooxanthellæ. No cinclides were observed.

Sphincter.—The sphincter (Pl. XXIX., fig. 6) consists of a large number of rounded muscle cavities, numerous above (fig. 7), and gradually diminishing proximally (Pl. XXIX., fig. 8).

Mesenteries.—The mesenteries have the usual arrangement of the family, with the following formula: 6 + 6 + 12 + 24. Of these, the second and third cycles are fertile; the fourth cycle consists of very minute mesoglœal projections, which do not extend beyond the endoderm. The retractor muscles are not powerful; they consist of slightly branched plaits, which extend a considerable distance along the mesenteries (Pl. XXIX., fig. 9). The parieto-basilar muscle consists of a few simple plaits on both sides of the mesentery, which are better developed on the side which bears the retractor muscle. Acontia are present, but not numerous in the lower portion of the cœlenteron.

Paraphellia lineata, H. & S.

Paraphellia lineata, Hadd. and Shackl., 1893; Proc. R. D. S., VIII., p. 130.

(Pl. XXIII., figs. 27, 28; Pl. XXIX., figs. 10, 11.)

Form.—Column slightly higher than broad, smooth; pedal and oral disk somewhat wider than column, both of about same diameter; tentacles very short, with a symmetry of six, about 100 in number (probably 6 + 6 + 12 + 24 + 48 = 96; mouth linear, with two gonidial grooves, an oral cone may be present.

Colour.—Column grey, sparsely speckled with pale brown; insertion of mesenteries show as alternate white and yellow lines; oral disk white, with numerous radial fine brown lines; the oral third (that which may be raised into the oral cone) of each radius with a thin central brown line, and near the base of the tentacles is a row of some half-dozen dark-brown spots: in the 12 primary radii, these fuse more or less to form a line; tentacles with a dark cloudy spot or core, at apex, upper third with several opaque rings; some are coloured with translucent red-lead at base, others are brown; most with five dark spots on each side; œsophagus buff; gonidial grooves pink.

Dimensions.—Height of column about 25 mm.

Habitat.—Between Orman's Reef and Gaba (Brother's Island), 6–7 fathoms.

This species can be readily distinguished externally from *P. Hunti*, and equally so by the character of the sphincter muscle. The only histological character that calls for any notice is the queer behaviour of the mesoglœa of the mesenteries; this often swells out at the base, and forms broad expansions which appear to enclose patches of the endoderm; the mesoglœa of the mesenteries sometimes shows a tendency to branch; but these may be artefacts due to imperfect preservation, or to faulty subsequent treatment.

The sphincter muscle is very characteristic; it is formed of a compact series of elongated and slightly branched muscle cavities, which, with a low power, give it a decidedly striated appearance (Pl. XXIX., figs. 10, 11).

PHELLIACTIS, Sim.

Chondractiniinæ of large size, with a very thick, smooth body-wall; scapus with a very delicate cuticle; capitulum naked; tentacles small, all with a thick rounded abaxial swelling.

P. Hertwigii, Simon (1892, Ein Beitrag zur Anat. Syst. der Hexactinien, p. 75) Simon describes, but gives no figures of this new genus and species; undoubtedly belongs to this sub-family as defined above; future investigations will show whether the genus will stand.

? STEPHANACTIS, Hertw.

"Chondractiniinæ, in which the body is elongated in the transverse axis, the base enclosing a cylindrical body, such as an Alcyonarian stem; column with a thick wall, but not covered by a well-marked cuticle; capitulum smooth, separated from the smooth scapus by a well-marked circular swelling." (McM.)

McMurrich (1893, p. 192) enters into a discussion of his reasons for abolishing Hertwig's family of the Amphianthidæ; but his position is not yet established, as we cannot be sure at present whether these forms are Sagartians.

Stephanactis: *S. tuberculata*, Hertw. (1882, p. 88); *S. abyssicola*, Mos. (Hertw. (1882, p. 90); *S. hyalonematis*, McM. (1893, p. 193).

Amphianthus: *A. bathybium*, Hertw. (1882, p. 91); *A. ornatum*, Hertw. (1888, p. 26).

AMMONACTIS, Verr.*

Chondractiniinæ (?), with an elongated, subcylindrical column, covered, as in Phellia, with a persistent epidermis extending to near the summit, naked above, with a lobe-like tubercle below each tentacle, distinct from the margin; tentacles long and numerous.

A rubricollum, Verr.

Family.—MINYADIDÆ, Andr.

Floating Actiniinæ, with a pedal disk which secretes a cuticicular hydrostatic float.

The group represented by the genus Minyas is so little known that it appears to me to be the wisest course to wait for further information before attempting to define its systematic position. Anatomical investigations have been made only by Carlgren and myself; and we had the same genus, and possibly the same species under observation. It is quite possible that the eight species associated together by Andres belong to different groups of the Actiniaria, for example: the *Actinia olivacea* of Lesueur is possibly a floating larva of one of the Stictodactylinæ: others may be larval forms of certain Actiniinæ; but the genus Minyas appears to be distinct, and to be representative of a special family of the Actiniinæ, but no gonads have as yet been observed in this genus. Carlgren suggests that Actiniaria with a decimal symmetry, and a cuticular pneumatic (hydrostatic) apparatus might constitute a new Tribe, the MINYÆ.

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* Proc. Essex Institute IV., 1864–5 (1866), p. 150.

STICHOPHORA, Brandt, 1835.

Non-tuberculated Minyadidæ, with twenty sulci externally; twenty pairs of mesenteries, the two mesenteries which arise from (and really form) each sulcus consist of a perfect and an imperfect mesentery, the corresponding pairs of which occur at the neighbouring sulci; two pairs of perfect directives; tentacles very small, bicyclic, forty in number; the endodermal sphincter muscle is reduced to a single fold; gonads not yet known.

I would provisionally include in this genus *S. Brandtii* (Andr.) [*Stichophora cyanæa*, Brandt—the specific name was pre-occupied by Cuvier for *Minyas cyanea*, so Andres rightly changed it, but wrongly erected a new genus (Phlyctænominyas) for it], and *S. torpedo* (Bell).

I think it well at present to keep these two species distinct; the body colour of the former is blue, and olive-green in the form I identify as *S. torpedo*.

The genus Minyas (type, *M. cyanea*, Cuv.) is apparently very similar, but the column is tuberculated. The other genera associated with Minyas are Plotactis, M. Edw.; Nautactis, M. Edw.; and Oceanactis, Mos.: probably all Andres' new generic names will lapse.

Stichophora torpedo, Bell.

Minyas torpedo, F. J. Bell, 1885, Journ. Linn. Soc. Zool. XIX., p. 114;
Hadd. and Shackl., 1893, Proc. R. D. S., VIII., p. 117.

(Pl. XXIII., figs. 29–33; Pl. XXX., figs. 5–11.)

Form.—Body wall thin; column of varying extensibility, but never as long as greatest breadth, may be quite short; pedal disk swollen, secreting in the centre a vesicular, cuticular float; oral disk of less diameter than column; tentacles in two rows of 20 each, all very short and thick, the inner cycle larger than the outer, the latter being mere tubercles; mouth oval, with a well-marked gonidial groove.

Colour.—Uniform olive-green.

Dimensions.—Greatest diameter 17 mm. (under ¾ in.)

Locality.—Floating on the sea at the Murray Islands, February, 1889.

Carlgren* has written a short and preliminary paper on a Minyad which is apparently identical with the above, or with *S. Brandtii*; assuming these species to be distinct, he gives only a diagrammatic figure illustrating the general disposition of the mesenteries. The essential point of the mesenterial arrangement

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* O. Carlgren. "Zur Kenntnis der Minyaden" Öfversigt af Kongl. Vetenskaps-Akad. Förhandl., 1894. Stockholm, p. 19.

is given in my diagnosis of the genus: a reference to Pl. xxx., fig. 5, will make this more clearly understood. It will be noticed that the section figured in Pl. xxx., fig. 6, passing through one pair of directives; the two elements of this pair, like all the other pairs of mesenteries are widely separated peripherally, but are close to the neighbouring element of the adjoining pair of imperfect mesenteries. In every case the associated perfect and imperfect mesenteries are attached to the bottom of one of the twenty sulci that longitudinally furrow the column. Two associated mesenteries are seen on a larger scale in Pl. xxx., fig. 7; and a very characteristic form taken by the retractor muscle of one of the perfect mesenteries is seen in Pl. xxx., fig. 8; the mesoglœal plaits are very fine, slightly branched, and few in number.

All the tissues of the body are thin, the general appearance of the ectoderm and endoderm is shown in Pl. xxx., figs. 9, 10, which also illustrate the very simple character of the endodermal sphincter muscle. So far as I can see, the mesenterial filaments have a very simple character (Pl. xxx., fig. 11). No gonads are present.

The float consists of vesicular layers of a cuticular secretion of the pedal disk; associated with it I find a large number of filaments which evidently belong to an Alga.

Order II.—STICHODACTYLINÆ, Andr.

Hexactiniæ with two kinds of tentacles, the main tentacles at the margin of the oral disk and accessory tentacles arranged radially in rows or groups on the oral disk. Numerous tentacles may communicate with one endocœl. Tentacles either similar or varied in form.

CORALLIMORPHIDÆ, . .	Corallimorphus, Corynactis.
DISCOSOMIDÆ, . .	Discosomoides, Discosoma, Radianthus, Stoichactis.
RHODACTIDÆ, . .	Rhodactis, Actinotryx, Ricordea, Heteranthus.
THALASSIANTHIDÆ, . .	Cryptodendrum, Heterodactyla, Actineria, Thalassianthus.
ACTINODENDRIDÆ, . .	Actinodendron, Megalactis, Acremodactyla.
PHYMANTHIDÆ, . .	Phymanthus, Thelaceros.

Family.—CORALLIMORPHIDÆ, Hertwig, 1882.

Stichodactylinæ with a marginal corona of tentacles, and accessory tentacles similar to those of the margin arranged in radial series, each series consisting of from one to many tentacles. Musculature throughout weak.

This family was constituted by Hertwig (1882, p. 21) to include the genus

Corallimorphus of Moseley (1877), with the following definition:—"Hexamerous Actiniæ with a double corona of tentacles, a corona of marginal principal tentacles, and a corona of intermediate accessory tentacles. Septa [mesenteries] slightly differentiated, all furnished with reproductive organs. Muscular system weak in all parts of the body. No circular muscle." He also draws attention to "an affinity between the Corallimorphidæ and Allman's genus, Corynactis." In the supplement to his "Challenger" Report (1888), Hertwig definitely places the genus Corynactis in his new family. In the meantime, Andres (1884, p 265) had placed Corynactis, Corallimorphus, and Capnea in a sub-family Corynactidæ, which, together with seven other sub-families, made up his family Stichodactylinæ. Gosse (1860, p. 278) had already allied Capnea, Aureliania, and Corynactis in a new family, the Capneadæ. I do not propose to say anything about Capnea, and Aureliania, as nothing is known of their anatomy.

CORALLIMORPHUS, Moseley.

Corallimorphidæ with the marginal and intermediate tentacles knobbed; marginal tentacles uniserial, varying in size according to position (6 + 6 + 12 + 24); accessory tentacles in hexamerous cycles, never more than one in a given radius. Mesenteries all fertile. Muscular system weak in all parts of the body; no sphincter muscle; feeble ectodermal muscle in body-wall.

Corallimorphus rigidus, Mos., 1877.
,, *profundus*, Mos., 1877.
,, *obtectus*, Hert., 1888.

CORYNACTIS, Allman.

Corallimorphidæ with the marginal tentacles alternately larger and smaller (28 or 32, or 56); accessory tentacles in tetramerous cycles, more than one in a single radius. Ectodermal muscle layer in body-wall; a feeble endodermal sphincter present.

C. viridis, Allm., 1846.
C. globulifera (Ehr.), 1834.
C. myrcia (D. & M.), 1866.
C. carnea, Stud., 1878.
(*cf.* Kwietniewski, Jen. Zeitschr. xxx., p. 597.)

C. hoplites, H. & S., 1893.
C. Australis, H. & D., 1896.
C. Hertwigi, n. n. for *C.* (?) *sp.* Hert. 1888, "Chall." Rep. Suppl., p. 10.

Corynactis hoplites, H. & S.

Corynactis hoplites, Hadd. and Shackl., 1893, Proc. R. D. S., VIII., p. 118.

(Pl. XXX., figs. 1–4.)

Form.—Column about twice as high as broad, smooth, pedal disk expanded; tentacles, capitate, of two kinds, (1) marginal and (2) centripetal, situated on the disk, the latter in at least two cycles; mouth can be extended into a short tube, finely ridged internally.

Colour.—Colour varied; (*a*) column burnt sienna-colour, with dark paired marks at the top of the scapus; tentacles translucent white, with a pink or white core at the swollen tip; mouth-cone speckled gray; throat orange; (*b*) similar, with pinkish-brown tips to tentacles; six pairs of marks on capitulum; (*c*) transparent grass-green, with brown streaks; tentacles with transparent green tips.

Dimensions.—Diameter of column about 8 mm.; height about 14 mm.

Habitat.—Between Orman's Reef and "The Brothers Island," 6–7 fms., August 18, 1888; also on fringing-reef, Mabuiag, October, 1888.

Body-wall.—The ectoderm, which is thrown into numerous folds in the specimen, consists of ciliated columnar cells with numerous oval gland cells, with unstained granular contents. The nuclei of the columnar cells are deeply stained, and are not irregularly placed in the cells, but appear in sections as a central band which lies nearer to the mesoglœa than to the periphery. There is a distinct layer of ectodermal muscle fibres.

The mesoglœa is homogeneous, stains deeply, and is of about the same average thickness as the ectoderm.

The endoderm forms ridges between every two mesenteries. It contains scattered small oval cells of a yellow-colour. There is a slight diffuse endodermal muscle which becomes better marked as the sphincter is approached.

The Sphincter Muscle.—Unlike *C. viridis*, which has no distinct sphincter muscle,* there is in *C. hoplites* a well-marked diffuse endodermal muscle (Pl. XXX., fig. 2). The mesoglœa is thrown into numerous deep folds which are occasionally branched.

Tentacles.—The ectoderm of the tentacles is very thick, at their extremities it is almost entirely composed of very long and narrow nematocysts each of which contains a distinct spiral thread (Pl. XXX., fig. 1). These nematocysts disappear as the disk is approached; the ectoderm also becomes thinner; and gland cells similar to those of the body-wall are found in the peripheral portion. The ectodermal muscular layer is well marked. The mesoglœa is thin. The endoderm

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* Cf. Haddon and Duerden, Trans. Roy. Dub. Soc., vi., 1896., Pl. VIII., fig. 11.

is throughout of about the same thickness as the ectoderm of the proximal region of the tentacles. It presents no features worthy of special note.

Disk.—The structure of the disk is similar to that of the proximal portion of the tentacles, no nematocysts, but numerous gland cells are present in the ectoderm.

Œsophagus.—The ectoderm of the œsophagus is thrown into numerous (about 24) folds. In the specimen of which I have transverse sections, there are three œsophageal grooves corresponding to the three pairs of directive mesenteries. Two of these grooves are close together, being separated by one pair of perfect between two pairs of imperfect mesenteries.

Mesenteries.—The mesoglœa is very thick in the peripheral portion of the mesenteries (Pl. xxx., fig. 4); the retractor muscles are very feebly developed. I have not noticed large nematocysts corresponding to those which occur so numerously in the endoderm of the mesenteries of *C. viridis.*

The arrangement of the mesenteries is as follows:—

D.—*1*, 2, 3, 4, 5, *6*, 7, 8, 9. D.—*10*, 11, *12*. D.—*13*, 14, 15, 16, 17, 18, 19, *20* = 23.*

Thus there are three directives, and the intervals between them contain respectively 7, 1, and 6 pairs of mesenteries, and each interval also contains two pairs of imperfect mesenteries. The latter are usually on each side of the directives. Mr. Duerden and I have shown an analogous lack of symmetry in *Corynactis Australis* (Trans. R. D. S., VI., 1896, p. 153), and I find the same obtains in *C. viridis*, one specimen of which has the following arrangement:—

D.—*1*, *2*, 3, 5, 6, *7*, 8, 9, 10, 11, 12. D.—*13*, 14, *15*, 16, *17*, 18, 19, *20*, 21, *22*, 23,
24, 25, *26*, 27, *28* = 30.

With two directives only one groove is marked, and there is a decided asymmetry in the disposition of the mesenteries.

Gonads.—None present in the specimen examined.

Apparently all the species of Corynactis externally closely resemble one another, and curiously the emerald green ring round the capitulum is characteristic of forms so widely distributed as European seas (*C. viridis*), off the coast of Buenos Ayres (*C. carnea*), and Port Philip, Australia (*C. Australis*). As has already been pointed out by Mr. Duerden and myself, the sphincter muscle differs in the various species, that of *C. carnea*, Studer, which lately has been described by Kwietniewski (Jenaische Zeitschr. xxx., p. 599, pl. xxvi., fig. 12), is somewhat similar to the sphincter of *C. viridis*. *C. hoplites* resembles *C. Australis* in possessing a thick mesoglœa in the body wall, and in the great thickness of the mesoglœa in the proximal (*i. e.* outer) portions of the mesenteries.

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* In the above formula D = a pair of directive mesenteries, the upright numerals are pairs of perfect mesenteries and the italic numerals pairs of imperfect mesenteries.

Family.—DISCOSOMIDÆ, Klunz.

Stichodactylinæ, with the column either smooth or furnished with verrucæ towards its upper portion. Oral disk usually of large size and lobed. Tentacles all of one kind, varying in form from long, slender, and pointed to very short and blunt; accessory tentacles in numerous radial rows or groups. Very numerous mesenteries, many of which are perfect; all the larger mesenteries are fertile (except the directives?). Sphincter muscle endodermal, strong, and circumscribed, more or less feebly developed, or absent.

Simon (Ein Beitrag zur Anat. und Syst. der Hexactinien Inaug.-Dissert. München, 1892), who has studied the type species of Discosoma (*D. nummiforme* and *D. tapetum*), gives the following table (p. 92):—

"I. On the very broad oral disk the tentacles are arranged in numerous radial rows, both in the exocœls (Interseptal-) and endocœls (Intraseptal-kammern):—

a. Tentacles like papillæ:
  Discosoma nummiforme (small form).
    Body-wall smooth; border of oral disk somewhat undulating; diffuse endodermal sphincter.
  D. fungiforme.
    Body-wall smooth; border of oral disk lobed.

b. Tentacles short, finger-like.
  D. anemone (large form).
    Body-wall, with suckers above; border of oral disk almost even; circumscribed endodermal sphincter.

II. On the slightly extended oral disk the tentacles are disposed in radial groups in the endocœls only.

a. Tentacles like papillæ:
  D. tapetum (moderate-sized form).
    Body-wall smooth, oral disk rounded; no sphincter.

b. Tentacles short, finger-like (and club-shaped).
  D. giganteum (large form).
    Body-wall smooth; border of oral disk distinctly lobed.
  (*D. molle?*)."

This family will require a good deal of working at before it can be satisfactorily classified. The four following genera appear to form a sequence; probably (*D.*) *giganteum* will be the type of a new genus:—

Sphincter absent; no verrucæ; tuberculiform tentacles.
Discosomoides: type, *D. tapetum*, Ehr.

Sphincter diffuse; no verrucæ; tuberculiform tentacles.
Discosoma: type, *D. nummiforme*, Leuck.

Sphincter restricted; with verrucæ; pointed long or short tentacles.
Radianthus: type, *R. Kuekenthali*, Kwietn.

Sphincter circumscribed; with verrucæ; pointed or blunt, moderately short or very short tentacles.
Stoichactis: type, *S. Kenti*, Hadd.

DISCOSOMOIDES, n. g.

Discosomidæ, with a smooth column and tuberculiform or papilliform tentacles; no gonidial grooves; numerous perfect mesenteries, all of which, excepting perhaps the directives, are fertile; sphincter muscle absent.

D. tapetum, Ehr.

DISCOSOMA, Leuck.

Discosomidæ, with a smooth column and tuberculiform or papilliform tentacles; no gonidial grooves; numerous perfect mesenteries, all of which, excepting perhaps the directives, are fertile; diffuse endodermal sphincter muscle.

D. nummiforme, Leuck.

RADIANTHUS, Kwietn.

Discosomidæ, with prominent verrucæ in the upper part of the body-wall. Oral disk broad and somewhat lobed, with numerous, pointed tentacles; marginal tentacles arranged in several cycles; accessory tentacles in numerous, radial, single rows; each row consists of more or fewer tentacles, according to the rank of the mesenterial chamber into which they open; two deep gonidial grooves. Mesenteries in numerous cycles, most of which are perfect; only the smallest mesenteries are sterile. Sphincter endodermal more or less diffuse (restricted*).

Dr. Kwietniewski has anticipated me in the naming of this genus, as I had

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*For the meaning of this term cf. p. 432.

previously come to the conclusion, from anatomical investigations, that certain forms collected by me, which, from an external examination alone, would be placed in the genus Discosoma would have to be referred to a new genus.

Our knowlege of this group of Actiniaria is still too slight for a satisfactory grouping of the species. If the genus Radianthus is to be characterised by a really diffuse endodermal sphincter of the type of the genus Actinia or Anemonia, then the species *R. macrodactylus* and *R. Malu* might have to be relegated to the genus Stoichactis.

At present the following species may be placed in this genus:—

R. Kuekenthali, Kwietn. "Actiniaria von Ternate." *Abhandl. Senckenb. nat. Gesellsch.* xxiii. 1897, p. 332.
R. macrodactylus (H. & S.).
R. Malu (H. & S.).

Radianthus macrodactylus (H. & S.)

Discosoma macrodactylum, . . . Hadd. and Shackl., 1893; Proc. R. D. S., VIII., p. 120.

(Pl. XXXI., figs. 1–3.)

Form.—Salver-shaped, owing to the great expansion of the oral disk, with numerous large suckers, crowded into a broad zone, on the upper portion of column; all the tentacles are long and very contractile, their tips are perforated; the accessory tentacles are placed in well-marked linear series; mouth with two gonidial grooves; the disk is bare of tentacles for a distance of 25 to 50 mm. (1–2 in.) from the mouth.

Colour.—Column olive-brown, darker above, with pale spots on upper portion; disk pinkish gray peripherally, passing into pale olive green, which shades into olive brown round the mouth; œsophagus delicate pink; tentacles dove-gray, with a yellowish sheen, which is most marked at the tip.

Dimensions.—Diameter of disk 250–300 mm. (10 to 12 in.) or more; mouth, 25 mm. × 57 mm.; tentacles 40 mm. ($1\frac{1}{2}$ in.) or more in length.

At first sight the corona of this species looks like that of a very large typical member of the genus Anemonia (Anthea), the coloration being very similar to that which may be found in some specimens of *A. sulcata,* but the fact of several tentacles opening into single mesenterial chambers proves it to be a Stichodactyline. On an examination of the surface of the oral disk, it is seen that one or two pairs of mesenteries occur between those pairs which enclose the bases of the tentacles.

Sphincter muscle.—The sphincter muscle (Pl. XXXI., fig. 1.) of this species is very small compared with the size of the polyp; it consists of several long, thin, slightly branched plaits of the mesoglœa (Pl. XXXI., fig. 2); but in some sections two of the distal plaits are very much larger than the others, and are richly branched (Pl. XXXI., fig. 3), and here we have an approach to a circumscribed sphincter. The latter figure also shows a section of a sucker. The endoderm contains numerous zooxanthellæ.

Radianthus Malu (H. & S.)

Discosoma Malu, . . . Hadd. and Shackl. 1893; Proc. R. D. S. VIII., p. 120.

(Pl. XXIV., figs. 1, 2; Pl. XXXI., figs. 4, 5.)

Form.—Column, soft, massive; upper portion with a broad zone of large, fairly widely separated suckers, to which pieces of shell often adhere; a slight but distinct crenulated parapet; oral disk of much greater diameter than column, and thrown into folds; mouth round, with two well-marked gonidial grooves; tentacles very numerous, contractile, may be reduced to mere filaments; the marginal tentacles are in two cycles, large, and of the same size; the accessory tentacles appear to arise anywhere on the disk, they usually occur in short radial rows, of these the tentacle situated nearest to the mouth is the largest.

Colour.—Whole body pale creamy yellow; the tentacles shade off into pink, and have rosy-red tips.

Dimensions.—Column about 100 mm. (4 in.) high; about 75 mm. in diameter; diameter of corona over 160 mm.; length of tentacles 22 mm.

Habitat.—(Of single specimen) surface of reef, Mer.

Sphincter muscle.—Still less conspicuous than in the last species is the sphincter of this species (Pl. XXXI., fig. 4). It consists of a number of fine, and often many branched plaits of the mesoglœa; distally there is a relatively great branch of these; their appearance is shown in detail in Pl. XXX., fig. 5. The sphincter sometimes appears to be lodged within two of the folds of the branched mesoglœal plaitings that characterise the body-wall of this species.

STOICHACTIS, n. g.

Discosomidæ usually of large size; column smooth below, and with verrucæ above. Tentacles vary in form from moderately short and subulate, to short and blunt, and even to quite small and capitate. Two gonidial grooves. Sphincter muscle strong and circumscribed. I think it is desirable to erect a new genus for those forms which have verrucæ in the upper portion of the column and a well-marked circumscribed sphincter, all of which have been previously placed under the genus Discosoma. The suckers are, as a rule, inconspicuous in the preserved specimens, and in this respect those specimens differ markedly from examples of the genus Radianthus.

S. Kenti (H. & S.); *S. Haddoni* (S.-Kent); *S. anemone* (Ellis) (= *A. helianthus*, Ellis: cf. McMurrich, Journ. Morph. III., 1889, p. 37); *T. Fuegiensis* (Dana) (Cf. McMurrich, Proc. U. S. Nat. Mus. xvi., 1893, p. 200).

Stoichactis Kenti (H. & S.)

Discosoma Kenti, . . . Hadd. and Shackl., 1893. Proc. R. D. S., VIII., p. 119. Saville-Kent, 1893, "The Great Barrier Reef of Australia," p. 144, chromo pl. 1. Saville-Kent, 1897, "The Naturalist in Australia," p. 219, pl. XXXIX B (wrongly described as *D. Haddoni*). (Pl. XXXI., figs. 6, 7.)

Form.—A very large Actinian; column narrower below than above, upper portion with a broad zone of large, crowded suckers; oral disk of considerably greater diameter than column, and thrown into well-marked lobes; tentacles extremely numerous, subulate, in continuous, rapid, irregular, waving movement; mouth usually with two gonidial grooves.

Colour.—Various; column usually grey, greyish olive green, light fawn or pinkish brown, passing into buff above, or brownish and rusty orange above, upper portion with pale or sometimes dull violet suckers; tentacles, ashy grey, fawn-coloured or brown, or cindery-brown; sometimes the tentacles have a magenta, pinkish lilac or green tip; sometimes the inner tentacles are all dark green; one variety has the oral disk, and the lower part of the tentacles pale sea-green, the upper part of the tentacles being magenta; in a rarer variety the tentacles are golden brown at their bases, and a rich royal blue distally; the oral disk being reddish brown, and orange-yellow round the mouth.

Dimensions.—Diameter of corona from 1 to 2 feet (300–600 mm.).

Habitat.—On reefs in Torres Straits.

Locality.—Occurs abundantly in shallow pools, at about half or three-quarters ebb, among the reef of the Great Barrier system from Torres Straits southwards to Mackay; and on Western Australia coasts as far south as Shark's Bay. The species may, therefore, be said to occur on the tropical coasts of Australia.

In his "Great Barrier Reef," Saville-Kent says:—"*Discosoma Kenti* almost invariably contains two or more specimens for percoid fish about 3 inches long, *Amphiprion percula*, Lacepede. On thrusting a stick into the oral orifice of the anemone the fish swim out, but return immediately to their residence within the gastric cavity of their host, on the removal of the stick. The ground colour of the fish is a bright orange-vermilion, interrupted by three pearly white cross-bands, which as well as the edges of the fins are bordered with black; in an allied species the red colour is replaced by black. Apparently several species of Amphiprion are commensal with this gigantic anemone, as is also a small flat crab.

Body-wall.—The body-wall is thin relatively to the great size of the polyp. The ectoderm is thrown into numerous elevations, similar to those described by McMurrich for *S.* (*Discosoma*) *anemone* (McMurrich, 1889, p. 39, pl. iii., fig. 16). These give to the surface of the column a slightly rough appearance in spirit specimens. The ectoderm in *S. Kenti* consists entirely of ciliated columnar cells, the structure of the verrucæ being similar to that of other parts. The mesoglœa is about as thick as the ectoderm, for it contains very numerous deeply staining nuclei, which appear to be drawn out into fine fibrils. There is a well-marked endodermal muscular layer. The endoderm contains numerous zooxanthellæ.

Sphincter Muscle.—There is a strong circumscribed sphincter muscle (Pl. XXXI., figs. 6, 7). The mesoglœal axis is very thick, and rather short, and has a tendency to divide into two branches. The fine mesoglœal plaitings are very numerous and intricate, occasionally anastomosing, so that some muscle fibres are completely enclosed in the mesoglœa. This occurs most markedly on the proximal aspect of the sphincter; that is, on the side towards the column, and away from the tentacles.

Disk and Tentacles.—The nervous layer of the ectoderm of the tentacles is well marked. The ectodermal muscular layer is weak. The endodermal muscular layer is, however, well developed, the fibres being supported by irregular, blunt mesoglœal processes. The structure of the mesoglœa is similar to the body-wall.

Mesenteries.—There are a great number of perfect mesenteries. There is a pair of directives at each of the two gonidial grooves; the arrangement of the rest of the mesenteries appears to be quite irregular.

Stoichactis Haddoni (S.-K.).

Discosoma Haddoni, S.-Kent, 1893—"The Great Barrier Reef of Australia," pp. 32, 144, phóto pl. xxi., chromo pl. ii.—Saville-Kent, 1897, "The Naturalist in Australia," p. 221.

(Pl. XXXI., fig. 8.)

Form.—Column massive, soft, upper portion with a comparatively narrow zone of somewhat crowded suckers; a slight but distinct crenulated parapet. Oral disk of much greater diameter than the column, and thrown into deep, irregular folds;

mouth rounded—two gonidial grooves; tentacles very numerous, forming a dense, very broad, marginal band, from which gradually diminishing bands of accessory tentacles extend for a variable distance along the disk, the larger radial groups of accessory tentacles extend towards the mouth for about three-fourths or more of the diameter of the disk. All the tentacles are short, columnar, and furnished with a spherical head with radiating lines from the apex.

Colour.—Very variable, "in one of the most ordinarily recurring varieties, the spheroidal, bead-like tentacles occur in irregularly mixed patches of grey, white, lilac, and emerald green; the disk being shaded with tints of grey, while the oral orifice is bordered with bright yellow." In a rarer variety "the oral centre was yellow, the general surface of the disk fawn-brown, and all the tentacles were a brilliant apple-green." The column may be greenish blue, somewhat brown above with mauve suckers; oral disk purple brown, but green round the mouth; gonidial lips tipped with magenta; tentacles brown, deep dark blue heads. Another variety was dark sea-green, with lilac suckers; tentacles white below, yellowish above; disk translucent grey.

Dimensions.—Expanse of oral disk from 1 foot to 18 inches (300–450 mm.).

Habitat.—At about half or three-quarters ebb. The tropical coasts of Australia. This species has the same distribution as, and is found along with, *D. Kenti.*

The foregoing description is largely compiled from the accounts of this species given by Saville-Kent. This author draws attention to the fact that a fish and a prawn are commensal with the polyp in Torres Straits. This fish is the brilliantly coloured *Amphiprion bicinctus,* one of the Pomacentridæ, and allied to the wrasses; the fish has two white transverse bands on a ground colour of orange vermilion. The prawn is perhaps a Palæmon; it is quite transparent, save for some yellow and deep-red spots. In Western Australian waters another species of Amphiprion is associated with the Actinian; it has three white bands and other distinctive characters, which Saville-Kent describes in his later volume.

Body-wall.—The structure of the body-wall in this species is very similar to that of *D. Kenti,* but I do not find deeply staining nuclei in the mesoglœa as in that species. The mesoglœa appears to have a fibrilar structure, the fibrils running for the most part parallel to the body-wall. The endoderm is destitute of zooxanthellæ.

Sphincter Muscle.—The circumscribed endodermal sphincter is much weaker than that in *D. Kenti.* The mesoglœal axis is short, narrow in the proximal part, and splays distally into an irregular fan-shape, from which finer plaitings are given off, which again give off short branches arranged in an irregularly pinnate manner (Pl. XXXI., fig. 8).

Tentacles.—Both the endodermal and ectodermal musculature of the tentacles is weak. The mesoglœa is of similar structure to that in the body-wall. There appear to be no zooxanthellæ present.

Mesenteries.—There are three pairs of directives in the specimen examined, corresponding to the three grooves. Two of these are close together, the third is at the opposite side of the œsophagus; but it is separated from one of the pairs of directives by about ten pairs of perfect mesenteries, and on the other side by about five pairs. Some of the ten pairs are, however, closer together than the five pairs. The arrangement of the imperfect mesenteries between the perfect pairs is quite irregular.

I place the two following species as a sort of appendix to the family Discosomidæ, as neither can be placed in its appropriate genus until it has been examined anatomically.

" *Discosoma nummiforme*," Leuck.

Mr. Saville-Kent, in "The Great Barrier Reef" (p. 150, chromo pl. iii., 13), allocates to the above species a small Discosoma, 50 mm. (2 inches) in diameter, which he found in Torres Straits and on the Queensland coast. The pentagonal disk and the column are usually a rich purple-brown, and the almost sessile spheroidal tentacles are for the most part of a brilliant emerald green; but some, usually the centripetal ones, are of a purple-brown.

I do not know this form, nor do I think, from Saville-Kent's description, that it is *D. nummiforme;* it may be the young of *S. Haddoni.*

" *Discosoma rubra-oris*," S.-Kent, 1893, " The Great Barrier Reef," p. 151, chromo pl. iii., fig. 12.

"The disk is more symmetrically ovate or circular, and the tentacles, while sessile and spheroidal, are mounted on projecting rugæ of the disk." The colour is various shades of dark and yellow green, disposed in alternate triangular bands from the periphery to the centre; the oral cone is of a brilliant magenta hue.

Family.—RHODACTIDÆ, Andr.

Phyllactininæ (pars), Klunz., 1877.

Rhodactidæ, Andr., 1883, p. 282.

Stichodactylinæ, with a smooth body, greatly expanded oral disk, and tentacles of two kinds. The margin is furnished with minute tentacles of the ordinary kind, arranged apparently in a simple cycle, while upon the surface of the disk, and separate from the marginal tentacles by a naked space, are numerous tuberculiform or lobed tentacles, arranged more or less radially. Sphincter muscle, endodermal, circumscribed, diffuse and very weak, or absent. The musculature throughout is very weak.

I have combined the definition of this family by Andres and McMurrich with the addition of calling the marginal tentacles "minute," and of recording the presence of a sphincter muscle in some genera. McMurrich points out that the very characteristic of the family, as a whole, is the excessive proportion of glandular cells in the endoderm, and the very slight development of nematocysts. As in the Discosomidæ, some of the forms are stated to be without a sphincter, others have a feeble, while others again have a well-developed, endodermal sphincter.

The following genera may be relegated to this family:—

Rhodactis.
Actinotryx.
Ricordea.
Heteranthus.

RHODACTIS, M. Edw. et Haime.*

Rhodactidæ, in which the edge of the oral disk is produced into subtentaculiform crenulations; the disk is covered with short tentacles, of which the outer rows and a row round the mouth are simple and conical, while those of the central zone have a very short, thick stem, surmounted by several short finger-like processes; each of these latter, and apparently some of the large simple ones, are set in depression of the disk, surrounded by a ring-like thickening of the disk. Circumscribed endodermal sphincter muscle; two gonidial grooves.

I have recast the definition of this genus, laying emphasis on the collared pits in the oral disk from which the larger complex tentacles arise and on the circumscribed muscle. For the knowledge of the latter fact I have to thank Dr. Carlgren, who is investigating *R. rhodostoma*, and who will, I believe, also describe a new species of this genus. Duchassaing and Michelotti describe two species—*R. Danæ* and *R. musciformis* (Mem. R. Acad., Turin, xxiii., 1866, pp. 131, 132); but so far as I can understand their account, neither species belongs to this genus.

R. rhodostoma (Ehr.), 1834, for bibliography cf. Andres, 1884, p. 283.
? *R .Howesii*, S.-Kent, 1893.

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* 1851; M. Edw. 1857, "Hist. Nat. Coral." i. p. 293.

? **Rhodactis Howesii**, S.-K.

Rhodactis Howesii, Saville-Kent, 1893, "The Great Barrier Reef of Australia," p. 150, chromo pl. iii., fig. 2.

Form.—Column somewhat elevated and conical when expanded, spherical when contracted. Tentacles thickly developed throughout the area of the disk. The inner circlet, of four or five simple capitate tentacles, is situated immediately around the mouth: the remaining tentacles are compound and irregularly palmate and pinnatifid, consisting of a central shaft, around the distal half of which from five or six to as many as twenty secondary pinnules may be developed. When the tentacles are expanded these pinnules are elongate and subcylindrical, while in the contracted condition they are drawn in closely to the central shaft, and are distinctly capitate or spheroidal.

Colour.—In one variety the polyps were liver-brown throughout, excepting the tips of all the tentacle-pinnules, which were a brilliant golden green. In the second variety the pinnule tips were a light pearl grey.

Dimensions.—Not given.

Habitat.—Both varieties were found growing, massed together in patches of considerable size, on the reefs adjacent to the Bay Rock lighthouse, Cleveland Bay, near Townsville, Queensland.

Like Saville-Kent, I am inclined to provisionally place this species under the genus Rhodactis, but the original description and the figures are too vague to render its identification at all certain.

ACTINOTRYX, D. & M.

Actinotryx, Duch. et Mich., 1860, p. 321; Andres (Actinothrix), 1884 (pars), p. 294.

Rhodactis, McMurrich (not of M. Edw.), 1889, Journ. Morph., p. 42; and 1897, Zoological Bulletin I. (Boston), p. 120.

Rhodactidæ, in which the edge of the oral disk is produced into subtentaculiform crenulations. The disk is covered with short dendritic tentacles. Endodermal muscle feeble and diffuse or absent. No gonidial grooves.

The West Indian species of this genus has been investigated by McMurrich, who found that there were a large number (48 to 150) of mesenteries, the majority of which were perfect, but there was no regularity in the disposition of the imperfect mesenteries; he suggests that normally all the mesenteries should be perfect.

The endocœls and exocœls are of equal size, and, owing to this and the very slight development of the longitudinal muscles, it is very difficult to orientate the pairs properly. Only one pair of directives was present in one specimen, and probably only one pair in another specimen, while in a third specimen no directives were present. Although the œsophagus is raised into strong folds, gonidia could not be distinguished. The circular muscles of the column are throughout exceedingly feebly developed, and no special sphincter muscle is present.

My observations agree very closely with those of McMurrich, except that I can demonstrate a feeble diffuse sphincter (Pl. XI., figs. 1, 2).

A. Sancti-Thomæ, D. & M., 1860.
A. bryoides (H. & S.), 1893.
A. mussoides (?) (S.-K.), 1893.

Actinotryx bryoides (H. & S.).

Rhodactis bryoides, Hadd. and Shackl., 1893; Proc. R. D. S. VIII., p. 121.

(Pl. XXV., figs. 1–3; Pl. XXXII., figs. 7–9).

Form.—Body salver-shaped, with a well-marked crenulated parapet; oral disk expanded, of even contour, concave with prominent oral cone; mouth rounded, stomatodæum with twenty-four furrows, but no gonidial grooves; one or two short, knob-like tentacles on most of the crenulations of the parapet; but the bulk of the tentacles are compound, and are grouped in numerous radial lines, twelve of which run up the oral cone; there is an annular clear space between the centripetal and the peripheral tentacles.

Colour.—Column buff, greyish brown, or cinder-colour; disk burnt-sienna colour; tentacles various shades of bluish green, some on the disk brown; the peripheral knob-like tentacles on the crenulations of the disk are greenish; œsophagus grey or pinkish.

Dimensions.—Diameter of disk about 32 mm. ($1\frac{1}{4}$ in.).

Habitat.—Surface of reefs, Murray Islands.

Sometimes this species is found erect and salver-shaped (Pl. XXV., fig. 1); at others it occurs partially imbedded in the sand, in such a way that the perphery of the oral disk touches the ground; the outer quarter of the disk forms the lip of a shallow crater, in the centre of which rises the oral cone, with a circular open mouth (Pl. XXV., fig. 2). The crenulation of the periphery of the oral disk consists of a larger and a smaller series; about seven or eight of the latter occurring between each of the former (Pl. XXV., fig. 3). The disk is only slightly retractile.

The very numerous dendritic tentacles on the oral disk give a mossy appearance to the polyp; the surface of the disk is mottled with various shades of green, dark-brown, and grey. Sometimes there are twenty-four dark radial bands, alternating with as many lighter ones; the latter are chiefly formed of larger tentacles of a pinkish grey colour, the former of smaller tentacles, mainly of a green or brown colour.

Mesenteries.—Owing to the vertical contraction of this form when preserved in alcohol, and to other distortions that occur, it seems to be almost impossible to get satisfactory transverse sections, and this renders the study of this species particularly difficult. I was not able, in the specimens I examined, to determine the arrangement of the mesenteries, their number is about sixty. Neither in the living specimens, nor in the two that were sectionised, could gonidial grooves be detected in the œsophagus. I was not able either to discover any directive mesenteries, though I cannot say positively that they are absent. The musculature of the mesenteries is very feeble, and the retractor muscle contains a few scattered simple, or but very slightly branched, mesoglœal plaits.

Sphincter Muscle.—I have been able to demonstrate the occurrence of a feeble diffuse sphincter muscle, the position and character of which will be best understood by a reference to Pl. XXXII., figs. 7, 8.

Various points in the structure of this species are indicated in Pl. XXXII., fig. 7; above the sphincter is seen the parapet, two of the complex tentacles are also seen; the endoderm of these and that of the under-surface of the salver-shaped expansion of the column contain zooxanthellæ; but these are absent from the endoderm of the oral disk, probably on account of the great thickness of the mesoglœa in this region. Fig. 9 is a more or less horizontal section through a portion of the disk, and this shows the endodermal stems of several tentacles piercing the thick mesoglœa, and also demonstrates that several tentacles arise from one endocœl.

Actinotryx mussoides (S.-K.).

Platyzoanthus mussoides, Saville-Kent, 1893, "Barrier Reef," p. 155, woodcut.

Form—Flat, exceedingly irregular in outline; margin of oral disk crenulated; tentacles exceedingly short, in most instances minutely lobate, and developed over the greater portion of the area of the expanded disk.

Colour.—Oral disk light greenish brown; tentacles reddish brown, and white tipped; œsophagus rose-pink.

Dimensions.—Diameter of oral disk from 359–450 mm.

Habitat.—Thursday Island.

I have recast Saville-Kent's account of this form; but this, and his outline sketch of the group of polyps, are too vague to determine whether this is a new species, or merely the foregoing species. It is almost certainly an Actinotryx.

RICORDEA D. & M.

Ricordea, . . .	Duch. et Mich., 1860; McMurrich, 1896, p. 46; Andres, 1884, p. 360.
Homactis, . . .	Verrill, 1868, Proc. Essex Inst. VI., p. 70.
Heteranthus, . .	(Klunz.) McMurrich, 1889, p. 46.
?Phialactis, . . .	Fowler, 1889, Quart. Journ. Micr. Sci., p. 148.

Rhodactidæ, with the oral disk covered with radially disposed tuberculiform tentacles. Sphincter absent (?).

McMurrich has discussed this genus (1889, p. 46); at first he discarded Duchassaing and Michelotti's name, adopting that of Klunzinger, but subsequently (1896, p. 188) he returned to the path of taxonomic virtue. I do not agree with him in making Heteranthus a synonym of Ricordea. In a later paper (1897, Zool. Bulletin, I., p. 119) he states that one specimen of *R. florida* had only one pair of directive mesenteries, and in another none were present.

I have no personal acquaintance with this genus; but it appears to me that the form described by Dr. Fowler under the name of *Phialactis neglecta* must be placed here. The chief points of difference between his species and *R. florida* are the absence (?) of crenulations to the oral disk (which, by-the-by, Duchassaing and Michelotti themselves overlooked), and the group of the globular or tuberculiform tentacles "sphæridia," on the oral cone. I am inclined to think that Verrill's *Discostoma fungiforme*, from Bonin Islands, south of Japan, is another species of this genus (l. c., 1868, p. 70), and I have very little doubt that *Homactis rupicola*, Verr., from Hongkong is one also.

R. florida, . .	Duch. & Mich., 1860.
R. rupicola, .	(Verr.), 1868.
R. neglecta, .	(Fowl.), 1889.

HETERANTHUS, Klunzinger, 1877.

Rhodactidæ, with short, but distinct marginal tentacles, forming a single row, and with the oral disk covered with tuberculiform tentacles arranged radially. Upper portion of the column with verrucæ.

This genus, with the disk tentacles reduced to mere papillæ, is very closely allied to Ricordea; indeed for some time I did not separate them, but the presence of marginal tentacles is a fair diagnostic character. In his species Klunzinger describes the margin of the disk outside the tentacles as being furnished with warted papillæ (*vielwarzigen Läppchen*) or clusters of small thickly-crowded pigmented tubercles.

Homactis rupicola, Verrill, is allied to this; but it would, perhaps, be safer to regard it as a species of Ricordea, as the marginal "tentacles" appear to be very small, broad, and flattened; in fact, they may very well be what I describe as the crenulations of the disk.

Heteranthus verruculatus, . . . Klunzinger, 1877; Korallth. Rothen Meeres, p. 84, Taf. 5, fig. 9.

Family.—THALASSIANTHIDÆ, McM.

Stichodactylinæ, with an entirely smooth body-wall, or with verrucæ, on the upper portion of the column; a greatly expanded oral disk, which may be thrown into definite and permanent lobes; tentacles of two kinds, branched or fimbriated, and globular; a circumscribed endodermal sphincter muscle.

I think it will be found that the following genera fall into fairly natural groups:—

CRYPTODENDRUM, .	margin of the oral disk entire; the globular tentacles form a complete sub-marginal ring.
HETERODACTYLA, .	margin of the oral disk entire or thrown into irregular, inconstant lobes; the globular tentacles form an interrupted ring.
ACTINERIA, . . .	margin of the oral disk thrown into very numerous small permanent lobes, each of which bears numerous short plumose tentacles on its oral aspect, and a group of globular tentacles on its aboral aspect.
THALASSIANTHUS, .	margin of the oral disk thrown into elongated, tentacle-like, permanent lobes, each of which bears moderately long serrated tentacles on its oral aspect, and a group of globular tentacles on its aboral aspect.

In his "Synopsis of the Polyps and Corals of the North Pacific Exploring Expedition" (Proc. Essex Inst., Salem, VI. 1868 (1870), p. 67), Verrill thus describes the new genus AMPHIACTIS: "Base broad, column covered with prominent verrucæ, arranged in vertical lines. Simple tentacles in several rows submarginal, with compound and much sub-divided, short, tentacle-like organs both outside and inside of them; the latter covering the disk more or less completely." *A. orientalis*, Verr., n. sp., Bonin Is. On the next page he describes the simple tentacles: "simple tentacles elongated, moderately stout, tapering, arranged in about three crowded rows, and quite numerous." Were it not that the simple tentacles are described as elongated and tapering, I should have no hesitation in regarding this generic name as a synonym of Cryptodendrum. It must be remembered that Verrill had only preserved material, and no anatomical details are to hand.

Probably SARCOPHIANTHUS, Less., belongs to this group, but we have not sufficient information respecting it.

CRYPTODENDRUM, Klunz., 1877.

Thalassianthidæ, with a smooth body-wall, or with small suckers on the upper portion of the column; a greatly expanded oral disk, which has its margin entire. Tentacles of two kinds: (1) very numerous, short branched tentacles disposed in radial groups on the general surface of the oral disk, and also in a single row along the periphery of the disk; immediately within the latter is a fairly broad band of short, thick, knob-like, adhesive tentacles. The edge of the column (capitulum) crenulated by the insertions of the mesenteries, but there are no acrorhagi. Mouth, large, rounded, œsophagus with two gonidial grooves. Strong, circumscribed, endodermal, sphincter muscle.

C. adhæsivum, Klunz.

Cryptodendrum adhæsivum, Klunz.

Cryptodendrum adhæsivum, . Klunzinger, 1877, "Die Korallthiere des Rothen Meeres," p. 86, Taf. VI., fig. 4; Studer, 1878, Monatsber. K. Preuss. Akad. Wiss. Berlin, p. 545; Kwietniewski, 1895, Jenaische Zeitschr. XXX., p. 600, Taf. XXVI., fig. 15; Hadd. and Shackl., Proc. R. D. S. (N. S.), VIII., 1893, p. 117.

(Pl. XXV., figs. 4–6; Pl. XXXII., figs. 5, 6.)

Form.—Body-wall thin, with numerous small suckers in the upper portion of the column; the upper edge of the column is crenulated by the mesenteries, but there are no marginal spherules. Column short; pedal and oral disk expanded, latter irregularly folded, entirely covered with tentacles, except for a narrow space round the mouth; the oral disk is feebly and very slowly retractile, but it cannot be entirely retracted. Mouth rounded oval; œsophagus finely folded with two gonidial grooves, which do not show when the mouth is closed, but are very apparent when the œsophagus is puffed out. Tentacles of two kinds—(*a*) small, simple or branched in radial series on disk; of these there can be made out 12 primary and 12 + 24 + 48 (= 96) rows of varying size: but they are in reality not graded with perfect regularity; there is also a single row at the periphery; (*b*) Between the last-mentioned marginal row and the remainder is a continuous border of short, thick, knob-like, adhesive tentacles (pl. xxv., fig. 6).

Colour.—Column translucent, yellowish white with irregular blotches of a pale olive green, or dull orange colour, each crenulation of the capitular margin has a white spot; oral disk translucent buff or cream, or madder lake; dendritic tentacles, pale translucent buff, with a greenish sheen in certain lights; the ectoderm is colourless, and the dark core shines through, the colour being probably due to the zooxanthellæ; or these tentacles have, in the mass, various shades of green and brown. The adhesive tentacles are pale translucent buff with a brown core at tip marked with pale radial lines; the ectoderm is colourless. Area round mouth and the œsophagus white.

Habitat.—Reef, Murray Islands.

The foregoing is a description of the specimens collected by myself in Torres Straits. It agrees so well, save for small differences of colour, with Klunzinger's description, that I can see no reason why they should not be the same species. Klunzinger's specimens from the Red Sea had a whitish body, with red, brown, or brownish yellow to orange-coloured spots and streaks; foot yellow, with yellow-red spots; tentacles brownish, variegated with reddish; tips white; the form of wart-like tentacles usually rose- or brown-red to grey; its marginal tentacles white. Studer describes his specimen as green. He obtained it in the Straits of Galewo, on the coast of Salwatti, N.-W. New Guinea. Kwietniewski has figured the sphincter muscle of this latter form; and it will be seen that, though it belongs to the same type of muscle, it differs considerably in detail, the mesoglœal plaits being much coarser and very irregularly developed. I expect this is a distinct species, but until we have more information about the original determination of this form, the name may stand. Of course it is quite possible that the specimen I collected may also be a new species; for the present I prefer to leave the matter as it stands. The presence of the suckers on the column may have been overlooked by previous observers.

I have not made out the arrangement and number of the mesenteries of this form. The sphincter muscle (Pl. XXXII., figs. 5, 6) is of the circumscribed type, a number of very fine branched plaits arising in a regular manner from a stout mesoglœal axis. The endoderm contains zooxanthellaæ.

Genus.—**HETERODACTYLA**, Ehr., 1834.

Thalassianthidæ, in which the oral disk is of much greater diameter than the column; the margin of the disk may be thrown into irregular and inconstant large folds; the peristome is bare, but the greater portion of the oral disk is covered with smooth tufted tentacles; at the margin is an interrupted series of tentacles bearing urticating spheres.

H. Hemprichii, Ehr. *H. hypnoides*, S.-K.

Heterodactyla Hemprichii, Ehr.

Heterodactyla Hemprichii, Ehrenberg, 1834, Korallth. des Rothen Meeres, p. 42; Milne Edwards, 1857, Hist. Nat. Cor. i., p. 298; Klunzinger, 1877, Korallth. des Rothen Meeres, p. 90, pl. 7, fig. 1; Andres, 1884, "Le Attinie," p. 298; Saville-Kent, 1893, "Barrier Reef," p. 147, chromo pl. iii., fig. 3.

Form.—Column cylindrical, short, with indistinct verrucæ; oral disk much wider than column, so that the polyp is salver-shaped, the edges often thrown into lobes. The central fifth of the disk is bare, but the remainder is covered with numerous short tentacles, which bear a variable number (up to a dozen or so) of filaments disposed irregularly at various heights along each tentacle. Along the border are short tentacles bearing a small number (about six, never more than ten) of spherical, pedunculated tubercles, "nematospheres"; occasionally the tentacles which bear the nematospheres are also provided with terminal filaments. Saville-Kent describes the tentacles as "more or less distinctly pinnate, developed singly or in interrupted rows near the centre of the disk, becoming more thickly massed as they approach the peripheral border."

Colour.—Column pale yellowish red, the upper portion spotted with violet; margin greyish; disk greyish blue, with brown streaks externally; tentacles greyish red, with white tips; nematospheres violet, with a green spot (Klunz.). Column pale pink, with vertical rows of carmine spots; oral disk light olive brown peripherally; pale lemon yellow in centre, and a variegated mixture of the two between; tentacles transparent lemon yellow, with an olive brown core; nematospheres brilliant translucent violet, with a vivid emerald green apical spot. In one specimen small patches of the tentacles were entirely lemon-yellow (S.-Kent).

Size.—Expanse of oral disk about 100–130 mm. (4–5 inches), S.-K.; height of column 50 mm. (2 in.); diameter of disk 120 mm. (4¾ in.), Klunz.

Habitat.—Red Sea and tropical coast of Queensland, from Torres Straits to Cape Flattery.

I have no doubt that Saville-Kent has correctly identified his form with that described by Ehrenberg and by Klunzinger. Although the following species was not obtained by him actually in the Straits, I have included it here, as there is every probability that it will be found there eventually; but it is possible that this will prove to be a member of the genus Thalassianthus.

Heterodactyla hypnoides, S.-K.

Heterodactyla hypnoides, Saville-Kent, 1893—"Barrier Reef," p. 148, chromo pl. iii., fig. 6.

Form.—Very similar to the preceding. The tentacles were minutely subdivided, and so crowded together on the convoluted surface of the oral disk, that they presented the aspect of aggregated tufts of fine, brightly-coloured moss. A few small scattered groups of tentacles were observed a little within the general mass; but they did not occur as isolated units or in radiating lines, as in *H. Hemprichii.* The nematospheres form considerably larger clusters, twenty to thirty being closely aggregated on one stalk. The centre of the disk is more bare of tentacles than in the other species, and the edge of the disk is puckered up with such complexity that, judging from Saville-Kent's figure, it looks like a wreath of green flowers, three deep; a group of nematospheres forming the centre of each flower.

Colour.—Column and oral disk light stone-grey, with a tendency to pale green; tentacles brilliant grass-green; nematospheres bright amethyst, slightly darker at the apex.

Habitat.—Barrier Reef, Cape Flattery.

ACTINERIA, Blainv.

Thalassianthidæ, with the margin of the oral disk thrown into very numerous, small, permanent lobes, each of which bears numerous short plumose tentacles on its oral aspect, and a group of globular tentacles on its aboral aspect.

A. villosa (Q. & G.). *A. dendrophora*, H. & S.

Actineria dendrophora, H. & S.

Actineria dendrophora, Hadd. & Shackl., 1893, Proc. R. D. S. VIII., p. 123.

(Pl. XXV., figs. 7–9; Pl. XXXII., figs. 1–4.)

Form.—Column soft, with verrucæ in vertical lines corresponding to the exocœls on the upper portion of the column; base slightly expanded; parapet with small swellings for the exocœl chambers below the outer row of large dendritic tentacles; oral disk greatly expanded, and irregularly folded or puckered, with its edge produced into lobes some 300 or 400 in number, and 10 mm. in length; the distal two-thirds of the aboral aspect of the lobes is closely crowded with globular, pedunculated tentacles, the oral or upper surface being covered with ramified tentacles; these latter extend along the disk, in radial series, to a greater or less extent, but none reach the mouth; alternating with the lobes are comparatively large dendritic tentacles; these are more aborally situated than the lobes; disk smooth, inclined to be crateriform in the centre, non-contractile; mouth rounded, on a cone with two gonidial grooves.

Colour.—Column pinkish; disk translucent pinkish brown, with a delicate green sheen; mouth pale; capitate tentacles pink, with a cream-coloured speck on tip (they look just like pink pearls); dendritic tentacles of same colour as disk, but, owing to their round contour, the green sheen is more apparent, and this is especially so on the finer branches, which thus appear decidedly green; pedal disk cream colour.

Dimensions.—Column height about 70 mm. ($2\frac{3}{4}$ in.); diameter 45–50 mm.; diameter of disk 125 mm. (5 in.).

Habitat.—Surface of reef, Mer.

This species is quite distinct from the only hitherto described species of the genus *A. villosa* (Quoy et Gaim.). The specific name is derived from the numerous small tree-like tentacles on the disk.

The marginal lobes are prolongations of the endocœls, there being no tentacles in the exocœls except the outermost large dendritic tentacles. I could not observe in the living animal the symmetry and multiples of the radii, partly because of the incipient fission, but more particularly, as is usual with these species with dendritic tentacles, on account of their apparent irregularity.

The body-wall is strengthened by a thick layer of mesoglœa; the endoderm contains zooxanthellæ, which are especially abundant in the tentacles.

The sphincter muscle consists of a large number of long, fine, slightly-branched plaits, which arise from a thick quadrate protuberance of the mesoglœa. Two appearances of the sphincter are shown in Pl. xxxii., figs. 3 and 4. This kind of sphincter is more of the type to which I have elsewhere applied the term "restricted."

The mesenteries are very numerous, and a large, but apparently indefinite, number are perfect; all the mesenteries which attain a certain size may bear gonads, but probably not the directives.

THALASSIANTHUS, Leuck.

Thalassianthidæ, with the margin of the oral disk thrown into long permanent lobes, which have the appearance of tentacles, and each of which bears a few serrated tentacles on its oral aspect, and a group of globular tentacles on its aboral aspect; the serrated tentacles may also occur on the oral disk proper.

Kwietniewski is the only zoologist who has investigated the anatomy of a member of this genus. He finds, in *T. Senckenbergianus*, "Actiniaria von Ternate," Abhandl. Senckenbergisch. naturf. Ges. xxiii., 1897, p. 337, that there are no directives, and an irregular number of perfect and imperfect mesenteries which have no definite arrangement. All the large mesenteries bear gonads. There is a circumscribed endodermal muscle with a stout mesoglœal axis.

T. aster. Leuck. *T. Senckenbergianus*, Kwietn.

Family.—ACTINODENDRIDÆ, n. f.

Stichodactylinæ of large size, with a smooth body-wall; oral disk produced into a number of long tentacle-like arms, which bear variously disposed dendritic or globular tentacles. Mesenteries few in number, and arranged on the ordinary Hexactinian plan; they are all fertile, with the probable exception of the directives; no sphincter muscle.

My studies on the type genus of this new family have rendered it quite apparent that Actinodendron must be finally separated from the genera Thalassianthus and Actineria with which they have been united since the days of Milne-Edwards. Kwietniewski ("Actiniaria von Ternate," 1897) has also arrived at a similar conclusion; and he suggests (p. 337) the new family Dendrianthidæ (which he does not define at all) for the genus Megalactis. Somewhat later in his inaugural dissertation, "Ein Beitrag zur Anatomie und Systematik der Actiniarien" (Jena, 1897), he suggests that Megalactis might be placed among the Acremodactylidæ, a family which he thus describes:—"Actinians with a pedal disk; smooth (or also warty?), body-wall, without a rim. No cinclides. Tentacles with simple or agglomerated branched evaginations, marginal, the inner larger than the outer. Sphincter absent. Mesenteries not very numerous. No acontia." In the absence of illustrations it is not very easy to understand this new family. As he gives as a synonym "Heteractidæ (pars)? Andres, 1883," it is evident that he, with McMurrich, regards this family as one of the Actininæ, in which the tentacles are more or less branched. For the present I still regard these forms as members of the Stichodactylinæ, and I am inclined to regard the "tentacles" as tentacular prolongations of the disk, analogous to those of Actineria and Thalassianthus, which bear small complex tentacles rather than tentacles proper, which are provided with branches.

Instead of introducing a new term into Actiniarian nomenclature, I take the name of the most important genus for the designation of the family. Probably Megalactis, and perhaps Acremodactyla, belong here.

Actinodendron.	? Acremodactyla.
Megalactis.	? Actinostephanus.

ACTINODENDRON, Blainv.

ACTINODENDRON, Blainville, 1830, p. 287, 1834, p. 320; Milne-Edwards, 1857, p. 295; Andres, 1883, p. 303. ACTINIA, pars, Quoy et Gaim., 1833.

Actinodendridæ with a smooth body; the oral disk is not expanded, but its margin is produced into forty-eight elongated non-retractile lobes, on which are situated the branched tentacles. Sphincter muscle absent (?). Twenty-four pairs of mesenteries in three cycles. All the mesenteries, except the directives, are fertile.

The earlier definitions of this genus refer only to external characters, as no anatomical investigation has previously been made of any of its species. I have not been able to discover a sphincter muscle, and it is very probable that it is altogether absent. All the specimens examined had the typical Hexactinian arrangement of the mesenteries; the retractor muscle of all the mesenteries is very strong, and consists of a broad band of closely set, relatively simple plaits The first two cycles (6 + 6) are perfect, and there is a pair of directives. The third cycle consists of twelve pairs of small, but by no means ill-developed mesenteries. All the mesenteries are fertile, with the exception of the directives.

Owing to the great development and prolongation of the œsophageal grooves, the directives are feebly developed even in the lower part of the cœlenteron, and so far as I could discover they were sterile. The endocœls of the twenty-four mesenteries are prolonged into the lobes of the oral disk, and these show a variable degree of prominence corresponding with the mesenteric cycle to which each belongs. The twenty-four lobes which correspond to the exocœls are distinctly smaller than the others, and are situated more towards the periphery of the oral disk. The œsophagus is large and deep, and provided with two large, very deep, and elongated gonidial grooves.

Actinodendron plumosum, n. sp.

Actinodendron arboreum (Q. & G.)	Hadd. & Shackl., 1893; Proc. R. D. S. VIII., p. 117, not of Quoy et Gaim.
,, *alcyonoideum*, .	Saville-Kent, 1893, "Great Barrier Reef," pp. 34, 146, pl. xxii. A., not of Quoy et Gaim.
,, *alcyonidium*, .	Saville-Kent, 1897, Naturalist in Australia, p. 223, fig., p. 224.

(Pl. XXIV., figs. 3–6.)

Form.—Column soft; no warts or suckers; transversely corrugated when contracted, smooth when extended. The oral disk is prolonged into forty-eight tentacle-like lobes, of which the outermost cycle of twenty-four are distinctly the smallest in size, though usually in a distended condition the lobes are, however, contractile, and are covered with branched tentacles, which appear to be spirally disposed; the fully developed tentacles have quite a tree-like appearance; the tips of the bluntly pointed branches have on their oral aspect two slightly diverging thickened oval patches; the column passes into the lobes without any specialised capitulum or parapet. Mouth oval, may be raised to a cone, with two gonidial grooves.

Colour (Specimen A).—Column uniform yellow; tentacles and oral disk cinder colour; the twenty-four radial areas corresponding to the exocœls yellowish, with dark-grey spots.

(Specimen B).—Column yellowish, but rather pinkish below, with irregular brown streaks, which reach from the lower border to about one-third to one-half of the height of the column; tentacles cinder colour, with a pale whitish green tinge; the characteristic colouration of the twenty-four radii occurs only on the outer half of the oral disk; the central area round the mouth uniform greenish, with irregular spots.

(Specimen C).—Column creamy; basal portion of the lobes yellowish, much brighter in colour aborally; tentacles cindery grey; oral disk slaty green; the peripheral portion of the twenty-four radial bands of a brighter yellow than the centripetal.

(Specimen D).—Column buff; lobes bright yellowish green; tentacles bright green, yellower towards their tips; oral disk brownish buff; the twenty-four radial bands creamy yellow, irregularly spotted with dark grey; œsophagus grey.

(Specimen E).—Column uniform pale grey green, with vertical paler lines corresponding to the insertion of the mesenteries.

(Specimen F).—Uniform grey green.

Dimensions.—Height of column, when fully extended, 200–230 mm. (8 to 9 inches); diameter of column 90 mm. or more (3½ inches or more); diameter of corona over 300 mm. (over 1 foot); lobes 75–100 mm. (3–4 inches) in length.

Locality.—Fringing reef, in tidal pools exposed to direct sunlight, Mer; February, 1889. Cape York and Western Australia (Lacepede Is.) S.-K.

In the foregoing description I have copied out my field-notes which referred to specimens actually before me. Saville-Kent (1893, p. 34) says their stinging power is nearly as powerful as the ordinary stinging-nettle, the rash persisting for several days. I have also been stung; but it did not affect me to the same degree. The same author (p. 34) found it "most abundantly in the pools of water left on the sandy flats at half or even one-quarter ebb." At Somerset, Cape York, the highly contractile column was imbedded in sand for 18 inches or more; the pedal disk was attached to a stone. "The colours are lacking in brilliancy, being chiefly represented by varying shades of light brown and white, which are probably conducive to its advantage by assimilating it to the tint of its sandy bed. When fully extended, the compound tentacles are elevated to a height of eight or ten inches, and bear a remarkable resemblance to certain of the delicately branching, light brown seaweeds that abound in its vicinity." On p. 146, Saville-Kent says that "the tentacles, or their arm-like homologues, are twenty-four in number." Evidently he made this statement from an inspection of the photograph that he published (Pl. xxii., fig. A), in which the outermost cycle of smaller lobes is not shown.

From the illustration given by Saville-Kent, there can be little doubt that he had this species in view, and that he should have called it *A. arboreum*, instead of *A alcyonoideum*.

Actinodendron glomeratum, n. sp.

Actinodendron alcyonoideum (Q. & G.), Hadd. and Shackl., 1893; Proc. R. D. S. VIII., p. 117.

(Pl. XXIV., figs. 7-9.)

Form.—Very similar to *A. plumosum*; but the prolongations of the oral disk are thicker, and the tentacles, with their branches, form irregularly conical bossy agglomerations, which are spirally disposed on the lobes; the branches have delicate stalks with a spherical head.

Colour.—Column a uniform dull greenish yellow, with paler vertical lines; oral disk central portion greyish, with irregularly disposed translucent spots. The primary radii deep green near the greyish centre, but becoming paler in colour peripherally, and extending as the lobes, with a pale creamy green colour; these radii are sparsely spotted with lilac or pale magenta. Between these are narrow radial bands, with dark spots. Lobes of disk pale creamy green above dark slaty or a deep green laterally; tentacles pinkish grey, with greenish tips.

Dimensions.—Diameter of corona, 200 mm. (8 in.).

Habitat.—Reef, Mer.

This is a rare species, and quite distinct from the other and common species.

In the preliminary description these two species were identified respectively with the *A. arboreum* and *A. alcynoideum* of Quoy et Gaimard, as we did not wish to run the risk of burdening the literature of the subject with superfluous synonyms. Even now I cannot feel quite certain on this point, as it is possible that the original figures may be drawn inaccurately, and the descriptions are not quite explicit enough. On the whole, I think it is best to adhere to my original impression in the field, and to regard the Torres Straits' specimens as new species. I have, however, not hesitated to re-define the genus so as to conform with my species.

The species of the genus, then, are:—

A. With the ultimate branches of the tentacles more or less bilobed:

1. The ten very long and thin lobes of the oral disk; each bear five or six ovoid stalked vesicles, which are beset with small bifid papillæ. The column has a distinct upper margin (New Guinea), . . *A. arboreum.*
2. The forty-eight moderately long lobes bear numerous dendritic tentacles. The column passes insensibly into the lobes (Torres Straits), ... *A. plumosum.*

B. With the ultimate branches of the tentacles capitate:

1. The sixteen (? thirty-two) long narrow lobes; each bear three or four ovoid stalked vesicles, which are beset with small capitate papillæ (Tonga), . . *A. alcyonoideum.*
2. The forty-eight stout lobes bear numerous, spirally arranged, irregularly conical, complex tentacles, the branches of which have spherical heads (Torres Straits), ... *A. glomeratum.*

Genus.—MEGALACTIS, Ehr.

Megalactis, . Ehrenberg, 1834; Korallth. Rothen Meeres, p. 39; Andres, 1884; Le Attinie, p. 302.

Actineria, . M. Edwards, 1857, Hist. Nat. Cor. I., p. 296; Klunzinger, 1877; Korallth. Rothen Meeres, p. 90.

Actinodendridæ, of large size, with a smooth, soft column; oral disk not broader than column; tentacles 6 + 6 + 12, long and thick, with numerous lateral ramifying relatively thick branches. The corona measures from 230–300 mm. (9 to 12 inches) in diameter.

No specimen of this genus has been anatomically studied; but we may, for the present, regard it as being nearly allied to, but quite distinct from, Actinodendron.

M. Hemprichii, Ehr. *M. Griffithsi*, S.-K.

Megalactis Griffithsi, S.-K.

Megalactis Griffithsi, . S.-Kent, 1893, "The Great Barrier Reef of Australia," pp. 35, 147, pl. xxii. B.

Form.—Lobes of disk or "tentacles" twenty-four in number, bearing laterally a large number of irregularly placed, relatively thick dendritic tentacles, the ultimate ramifications of which have pointed ends.

Colour.—Tentacles usually a clear brown or French grey, with a distinct pale greenish stripe running up their centre; the basal halves of the tentacles of the specimens from Warrior Island photographed by Mr. Saville-Kent were alternately of a pale lilac and pale sea-green hue, the ultimate ramifications being grey and buff; the oral disk various shades of grey and buff with twenty-four radiating white lines with dark spots corresponding to the mesenteries; the six primary radii, that is those corresponding to the first cycle of tentacles, have a central broad white line radiating from the mouth to about a quarter or one-third the diameter of the disk; the secondary radii have similar but shorter white lines.

Dimensions.—The diameter of the corona is about 230 mm. (9 in.).

Habitat.—Torres Straits. Unlike the two species of Actinodendron, this species prefers the shelter of some rocky or coral boulder to sandy flats and full sunshine. It does not possess the distinct urticating properties of Actinodendron.

The above description is compiled from Saville-Kent's descriptions, as I am not acquainted with the form. It appears to be distinct from the only other recorded species of the genus, *M. Hemprichii*, Ehr. The latter species is described and figured as having twenty tentacles (10 + 10), but this may be an individual peculiarity.

Klunzinger describes the ultimate branches of the tentacles as being club-shaped in the species from the Red Sea, whereas, judging from Saville-Kent's photograph, these have pointed ends, and have altogether quite a different character from those of the older species.

? **ACREMODACTYLA**, Kwietn.

Actinodendridæ with a smooth body-wall, no marginal fold. The pedal disk is not sharply separated from the column. The tentacles comparatively large, in several cycles, covered with numerous branched prolongations. The angles of the mouth with strong triple swellings. All the mesenteries perfect and provided with gonads. Sphincter absent.

Acremodactyla Ambonensis, Kwietn.

Kwietniewski (Inaug.-Dissert., 1897, p. 19) describes a new genus and species which he terms *Acremodactyla Ambonensis*. There are forty-eight tentacles and twenty-four pairs of mesenteries. As mentioned above, he regards this form as the type of a new family. The question must be left for the present whether the "arms" are true tentacles with branches or tentacle-like prolongations of the oral disk which bear the reduced tentacles.

? **ACTINOSTEPHANUS**, Kwietn.

Actinodendridæ very similar to Acremodactyla, but with numerous conical prolongations of the tentacles, and with the directive mesenteries sterile.

Actinostephanus Hæckeli, Kwietn. (l. c., p. 23).

Besides the differences mentioned in the generic description the transverse musculature of the mesenteries is better developed than in the last species; otherwise the two forms are closely allied.

I suspect that the genera Acremodactyla and Actinostephanus are one and the same with Actinodendron. The question as to the distinctiveness of the specific forms must be left for the present.

Family.—PHYMANTHIDÆ. Andr.

Stichodactylinæ, with a column which is usually smooth below and verrucate above; the oral disk is not of much greater diameter than the column; marginal "tentacles" with lateral tubercles, or more or less complicated frondose appenpages; the tentacles on the oral disk are small, wart-like, and arranged in radial rows; sphincter muscle very feeble, diffuse, endodermal, or absent; at least twelve pairs of perfect mesenteries, all of which, including the two directives, are fertile.

At present there are only two genera in this family—Phymanthus and Thelaceros; the only distinction between them being, so far as I can make out, that the column of the latter is quite smooth. It is possible that a distinction will subsequently be made between those forms with tubercles and those with branched appendages on the "tentacles." I have spoken of the marginal prolongations as "tentacles." I admit this may be illogical, since I am inclined to regard the somewhat similar processes in the Actinodendridæ as prolongations of the oral disk; but I will leave this point for future discussion.

PHYMANTHUS, M. Edw.

Phymanthidæ, with the upper portion of the column provided with longitudinal rows of verrucæ, and with a very feeble diffuse endodermal sphincter muscle, or none at all.

This genus was erected by Milne-Edwards (1857, p. 297) for the *Actinodendron loligo* of Ehrenberg. This species has subsequently been well described and figured by Klunzinger (1877, p. 87); but the figure drawn by him (pl. vi., fig. 7) differs in so many details from the previously unpublished drawing by Ehrenberg (pl. vii., fig. 3), that they scarcely seem to be the same species. *P. crucifer* (Les.), as described by McMurrich (Journ. Morph., 1889, p. 51), appears to resemble the latter form; while the species known as *P. pinnulatum*, Mart., *P. muscosus*, H. & S., and *Thelaceros rhizophoræ*, Mitch., appear to be allied to the first type; indeed I should not be surprised if these three proved to be the same species.

McMurrich was the first to give any anatomical description of this genus. The mesenteries are arranged in four cycles in *P. crucifer*, "of which the first consists of twelve mesenteries, which are attached to the stomodæum throughout its full extent; the second, likewise of twelve, has them attached only about half-way down the stomodæum"; the remainder are entirely imperfect; "all the mesenteries, even the directives, are gonophoric." "There is no special sphincter muscle distinct from the ordinary endodermal muscle layer of the column, and, consequently, there is no infolding of the disk in contraction."

Klunzinger (1877, p. 87) refers in a footnote to a Phymanthus in the Berlin Museum, with much branched appendages to the tentacles which Martens collected at Singapore, and which he named *P. pinnulatum.* I do not know whether this form has been technically described.

P. loligo (Ehr.).
P. crucifer (Les.).
P. pinnulatum, Mart.
P. muscosus, H. & S.

Phymanthus muscosus, H. & S.

Phymanthus muscosus, Hadd. and Shackl., 1893, Proc. R. D. S., viii., p. 122; Saville-Kent, 1893, "Barrier Reef," p. 149, chromo pl. iii., fig. 5.

(Pl. XXV., figs. 10–14; Pl. XXXI., fig. 9.)

Form.—Column soft, lower portion smooth, upper portion of column with forty-eight rows of small wart-like suckers, which gradually increase in size from below upwards, and culminate in a crenulated parapet; disk flat, completely retractile; mouth small, round; the two gonidial grooves are not ordinarily apparent in the live animal; "tentacles," ninety-six in number, bearing lateral and symmetrical dendritic appendages, which are alternately large and small; on the oral disk are numerous wart-like tentacles arranged in radial rows.

Colour (A).—Column pale slaty grey, darker above than below; central portion of disk greenish, with a large number of irregular scattered small white rings, with dark centres; this area is darker peripherally; outer portion of disk creamy or dull white, mottled or spotted with dull greyish green; tentacles pale slaty grey on aboral aspect, and greenish yellow on oral surface, with a pink line down the centre (orally); appendages nearly white.

(B).—Column greenish grey, paler below; disk green, with dark spots (? low tubercles); tentacles, aboral aspect slaty grey, oral aspect with a pinkish central line; appendages greenish.

(C).—Column dull reddish buff below, passing into dull slaty green above, pale buff, with dirty white spots; disk not visible; tentacles slaty grey aborally; magenta streak on oral aspect; branches deep green.

Dimensions.—Height, 250–500 mm. (10–20 inches); diameter of corona, 500–750 mm. (20–30 inches) or more.

Habitat.—Surface of fringing reef, Mer; Barrier Reef (S.-K.).

"The variations of colour to which this species is subject are numerous. In one of the commonest varieties the disk and tentacles are various shades of olive-green, the shafts of the tentacles being the darkest. In a second variety the shafts of the tentacles are alone green, their pinnules and all portions of the disk being a pinkish brown. In a third variety the prevailing ground colours of the disk and tentacles are shades of light greenish grey; some of the latter being also crimson-tipped. A crimson line runs on the central shaft of each tentacle and the pinnules in this variety, while usually pale green, are in some examples nearly white" (Saville-Kent).

The twenty-four pairs of perfect mesenteries are fertile, and have a strongly developed retractor muscle. The diffuse endodermal sphincter is very feebly developed (Pl. XXXI., fig. 9), but there is no doubt as to its existence. The endoderm is crowded with Zooxanthellæ.

THELACEROS, Mitch.

Phymanthidæ, with a smooth column and no sphincter muscle.

P. Chalmers Mitchell (Quart. Journ. Micr. Sci. xxx., 1890, p. 551) described a new Actiniarian from Celebes, which he named *Thelaceros rhizophoræ*, and which he regarded as the type of a new family, the Thelaceridæ. Were it not that Chalmers Mitchell states clearly "the column was quite smooth—there were no warts, knobs, or ridges, and there were no cinclides; there were no marginal spheres"—I should place this form under the older genus Phymanthus; the species has many resemblances to *P. muscosus.*

INCERTÆ SEDIS.

Physobrachia Douglasi, S.-Kent.

Physobrachia Douglasi, S.-Kent, 1893—"Great Barrier Reef," p. 150, chromo pl. iii., figs. 9, 10.—Saville-Kent, 1897, "Nat. in Australia," p. 222, with fig.

Form.—Body relatively small, depressed; tentacles long and thick, with inflated, bladder-like tips.

Colour.—Column light or reddish brown, shafts of tentacles clear dark brown, claret, or purple; swollen extremities delicate emerald green, with small white tips. In the Western Australian form, the shafts of the tentacles were usually either a transparent dark myrtle green or a clear brown, and the inflated extremities pure white or palest lilac, with a minute crimson tip.

Habitat.—Social; in crevices of coral rock, Torres Straits and West Australia.

Nothing more is known about this form.

EXPLANATION OF PLATE XXII.

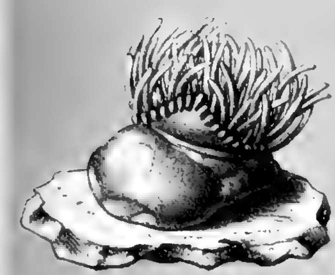
PLATE XXII.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Figure.

1. *Actinia citrina* (H. and S.), (p. 416), from a spirit specimen, nat. size.
2. ,, ,, from life, slightly larger than nat. size.
3. *Anemonia Ramsayi* (H. and S.), (p. 420), from life, nat. size.
4. ,, ,, (H. and S.), (p. 420), from life, nat. size.
5. ,, *Kwoiam* (H. and S.), (p. 422), from life, half nat. size.
6. *Actinioides Dixoniana* (H. and S.), (p. 424), from life, slightly larger than nat. size.
7. ,, *Papuensis*, n. sp. (p. 426), from a spirit specimen about nat. size.
8. ,, *Sesere* (H. and S.), (p. 428), from life, about twice nat. size.
9. ,, ,, sketch of upper portion of column.
10. *Macrodactyla aspera* (H. and S.), (p. 431), from life, about nat. size.
11. ,, ,, sketch of a tentacle with its radius.
12. *Aulactinia Gelam* (H. and S.), (p. 442), sketch from life, the column should be much longer.



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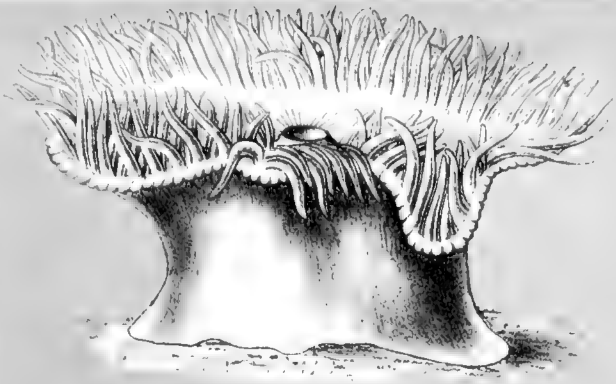

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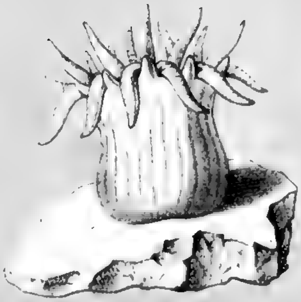

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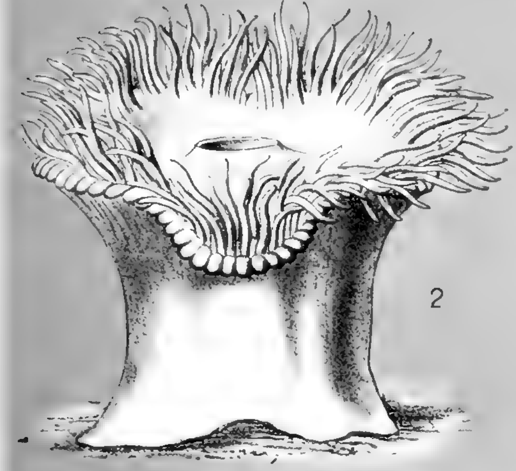

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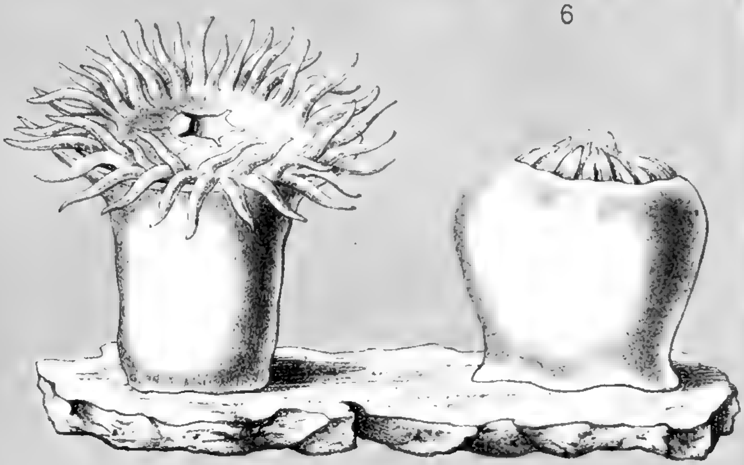

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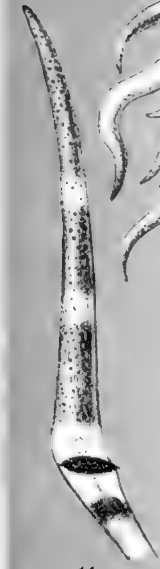

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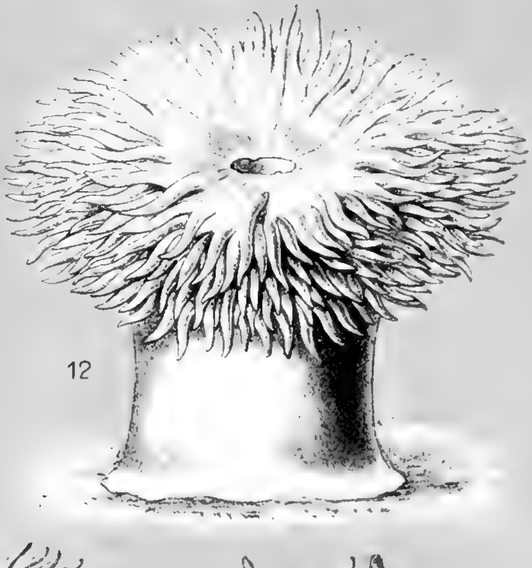

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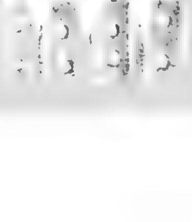

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EXPLANATION OF PLATE XXIII.

PLATE XXIII.

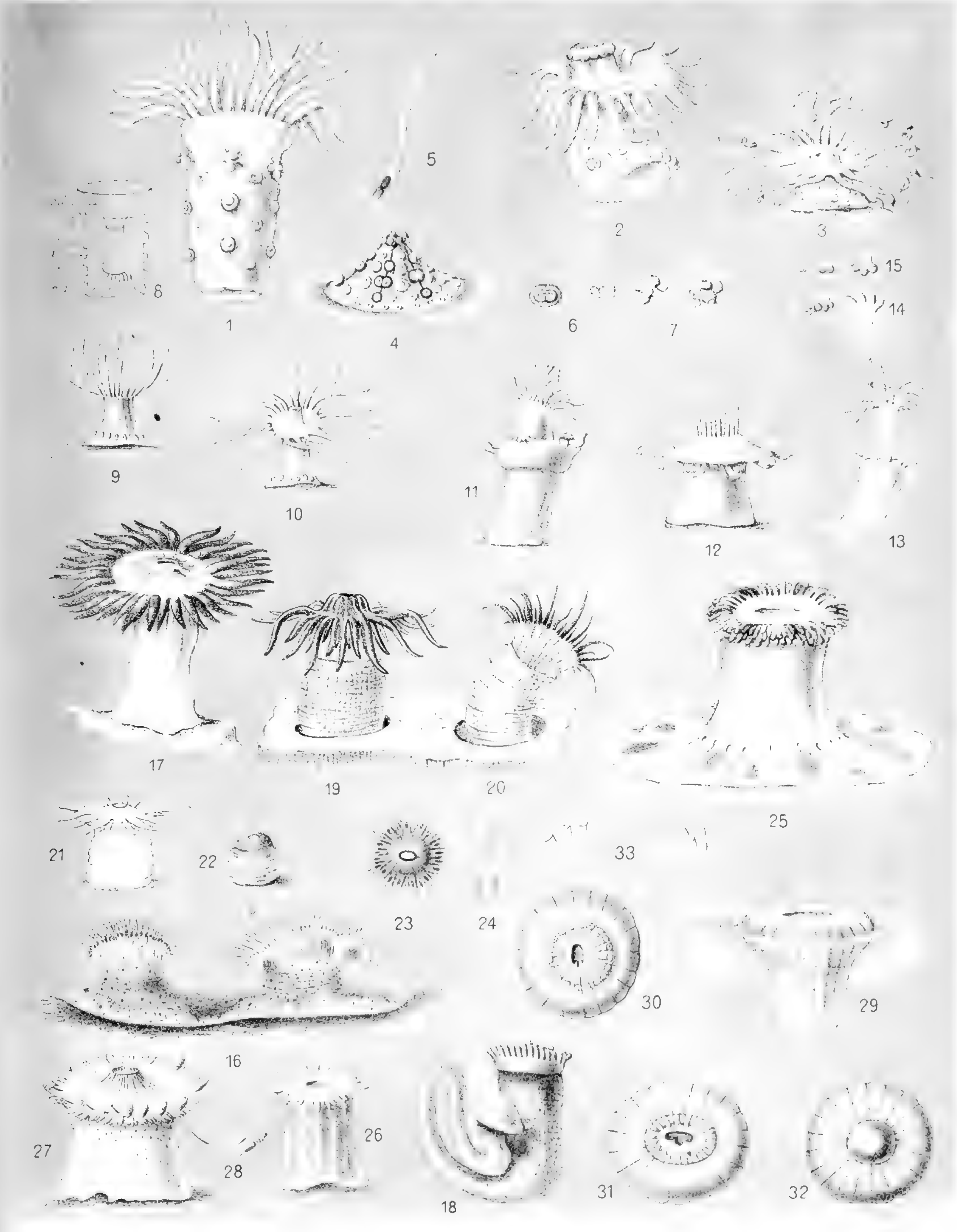
LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Figure.

1–3. *Alicia Rhadina* (H. and S.), (p. 433), from life, in various states of expansion.
4. ,, ,, ,, ,, from life, contracted.
5. ,, ,, ,, ,, tentacle.
6. ,, ,, ,, ,, simple vesicles.
7. ,, ,, ,, ,, compound vesicles.
8. ,, ,, ,, ,, diagram of a vertical optical section of a polyp, the tentacles are omitted.
9, 10. *Bunodeopsis Australis*, n. sp. (p. 435), from life, in various states of expansion.
11–13. *Hoplophoria cincta* (H. and S.), (p. 438), from life, in various states of expansion.
14. ,, ,, ,, ,, side and upper views of a large acrorhagia.
15. ,, ,, ,, ,, upper view of three acrorhagi in various stages of growth.
16. *Sagartia Milmani* (H. and S.), (p. 449), from life, nat. size. In this specimen fission has resulted in two polyps which are not yet quite separated from one another.
17. ,, *plebeia*, n. sp. (p. 451), from life, nat. size.
18. *Phellia vermiformis*, n. sp. (p. 454), from a spirit specimen, nat. size.
19, 20. ,, *sipunculoides* (H. and S.) (p. 454), from life.
21. ,, *Devisi* (H. and S.) (p. 455), side view, from life.
22. ,, ,, ,, ,, contracted specimen, from life.
23. ,, ,, ,, ,, upper view of corona, from life.
24. ,, ,, ,, ,, tentacle, from life.
25. *Calliactis Miriam* (H. and S.), (p. 457), from life.
26. *Paraphellia Hunti* (H. and S.), (p. 461), from life, × 2 diam.
27. ,, *lineata* (H. and S.) (p. 462), from life.
28. ,, ,, ,, ,, a tentacle and its radius.
29. *Sticophora torpedo* (Bell), (p. 464), from life, as seen floating in the water, but the float is not well rendered.
30, 31. ,, ,, ,, ,, oral aspect under different conditions.
32. ,, ,, ,, ,, aboral aspect, showing float.
33. ,, ,, ,, ,, upper and lateral views of tentacles.

Plate XXIII



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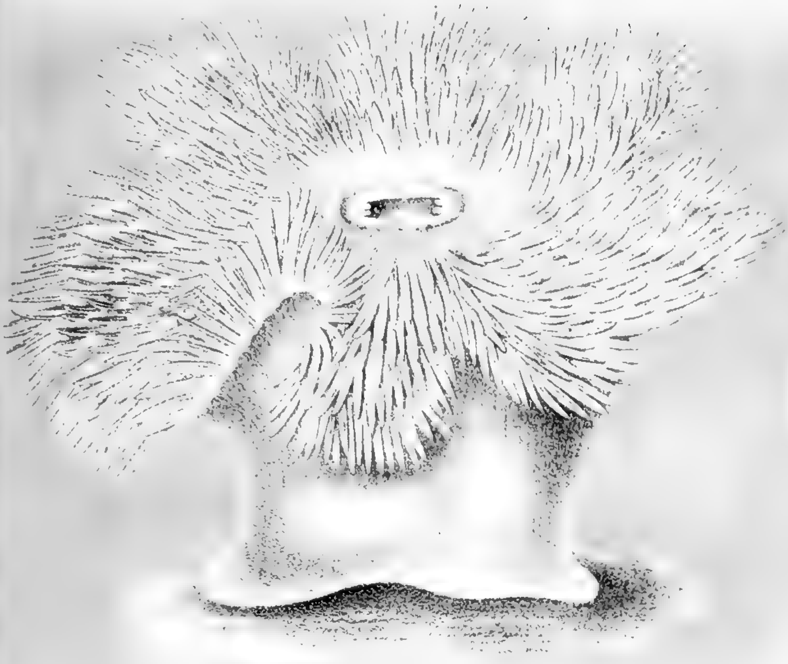
EXPLANATION OF PLATE XXIV.

PLATE XXIV.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Figure.
1. *Radianthus Malu* (H. and S.), (p. 472), from life.
2. ,, ,, ,, ,, sketch of upper portion of column.
3. *Actinodendron plumosum*, n. sp. (p. 490), from life.
4. ,, ,, ,, ,, small tentacle.
5. ,, ,, ,, ,, large tentacle.
6. ,, ,, ,, ,, (*a*) oral, (*b*) aboral, (*c*) lateral views of the end of a branch of a tentacle.
7. ,, *glomeratum*, n. sp., (p. 492), sketch of portion of corona, from life.
8. ,, ,, ,, ,, small tentacle.
9. ,, ,, ,, ,, large tentacle.



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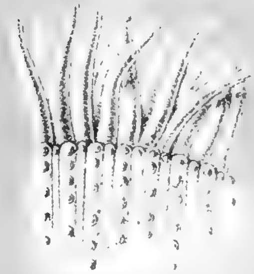

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A. C. H. del.

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EXPLANATION OF PLATE XXV.

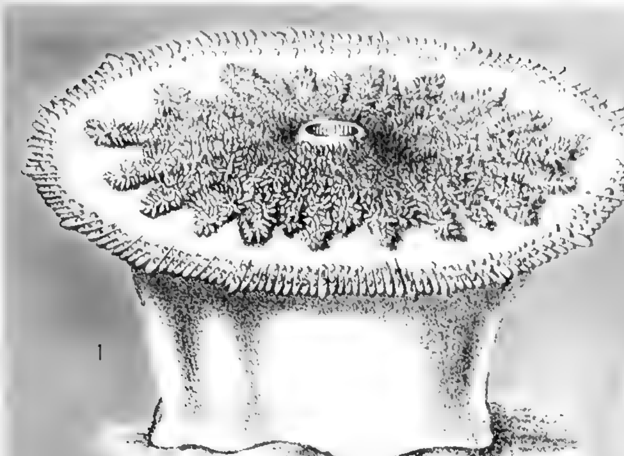
PLATE XXV.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Figure.

1. *Actinotryx bryoides* (H. and S.), (p. 479), from life, × about 2 diam.
2. ,, ,, ,, ,, imbedded in sand.
3. ,, ,, ,, ,, portion of the oral disk, from above.
4. *Cryptodendrum adhæsivum* (Klunz), (p. 483), from life, a little more than nat. size.
5. ,, ,, ,, ,, various accessory tentacles from the oral disk.
6. ,, ,, ,, ,, sub-marginal tentacles.
7. *Actineria dendrophora* (H. and S.), (p. 487), from life, about nat. size.
8. ,, ,, ,, ,, side view of lobes of the oral disk.
9. ,, ,, ,, ,, aboral view of the same.
10. *Phymanthus muscosus* (H. and S.), (p. 496), from life, about one-half nat. size.
11. ,, ,, ,, ,, from life.
12. ,, ,, ,, ,, from life, contracted.
13. ,, ,, ,, ,, oral aspect of "tentacle."
14. ,, ,, ,, ,, lateral branches of "tentacle."
15. *Ixalactis simplex* (H. and. S.), (p. 443), from life, about one-third nat. size.
16. ,, ,, ,, ,, portion of column.
17. ,, ,, ,, ,, side view of a tentacle.
18. ,, ,, ,, ,, oral aspect of a tentacle.
19. ,, ,, ,, ,, aboral aspect of a tentacle.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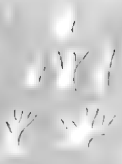
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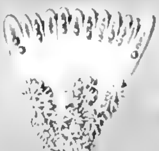
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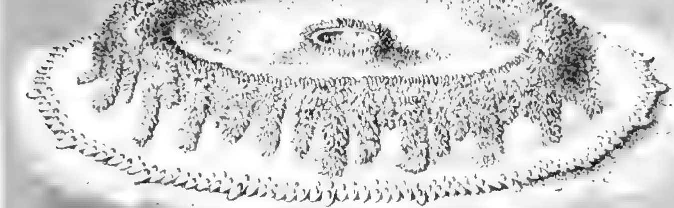
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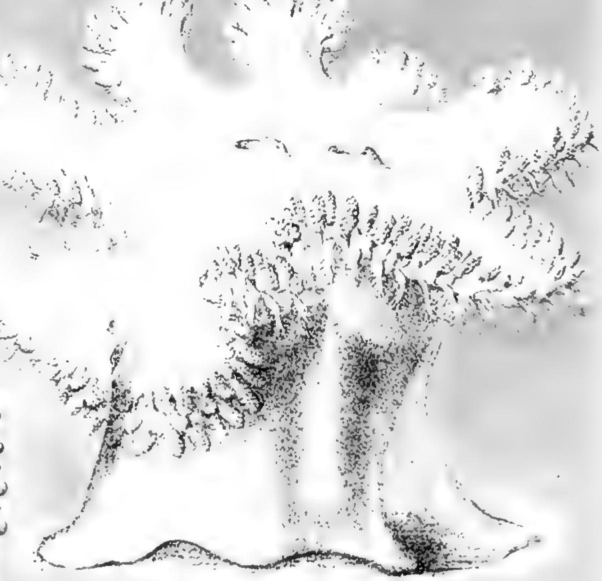
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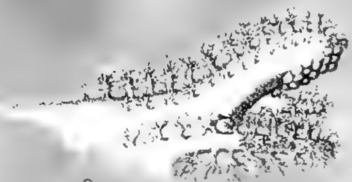
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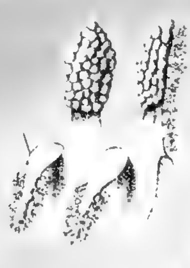
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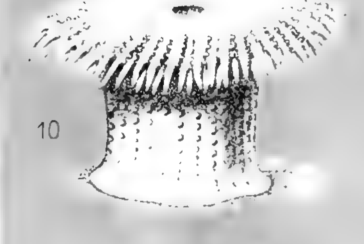
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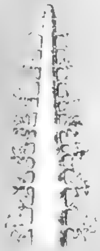
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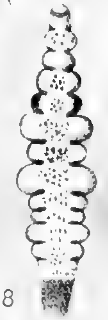
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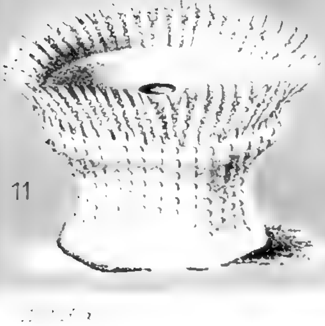
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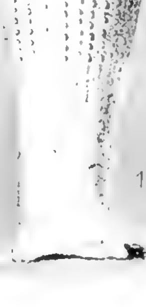
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EXPLANATION OF PLATE XXVI.

PLATE XXVI.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Actinia citrina (H. and S.), (p. 416).

Figure.

1. Vertical section of half a polyp.
2. Section of the sphincter muscle.
3. Dissection of a perfect mesentery.
4. Transverse section of a tentacle.
5. Vertical section of a part of the body-wall.

Anemonia Ramsayi (H. and S.), (p. 420).

6. Vertical section through upper portion of column and of a tentacle, × 500.
7. Transverse section through portion of a mesentery, × 100.

Anemonia Kwoiam (H. and S.), (p. 422).

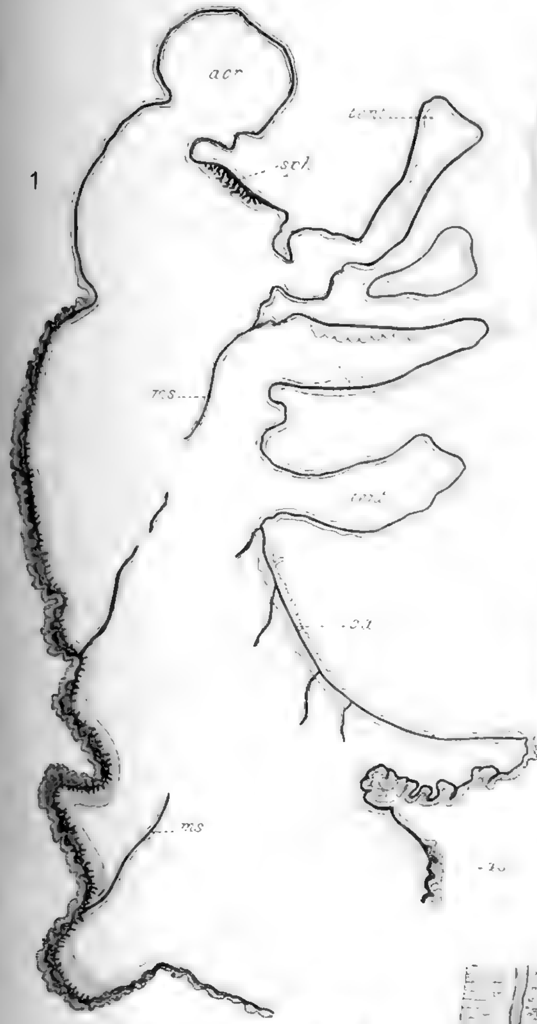
8. Vertical section of upper part of body-wall, × 15

9, 10. Two sections of the sphincter muscle, × 100.

11. Vertical section of a part of the body-wall, × 100.

Plate XXVI.

1



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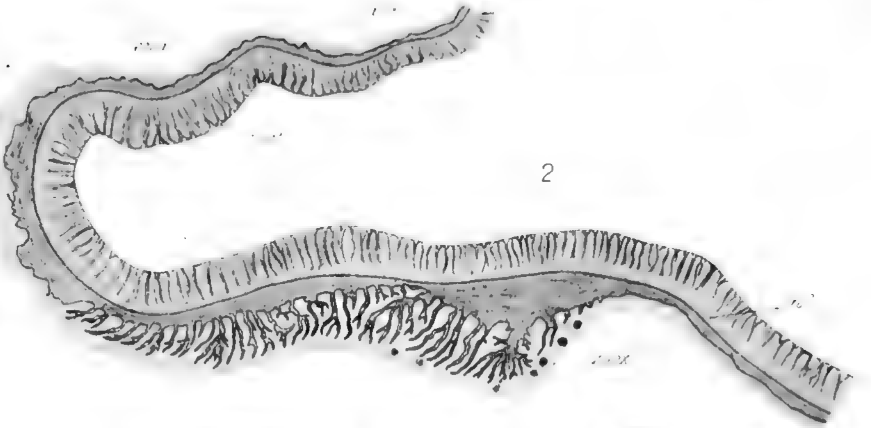

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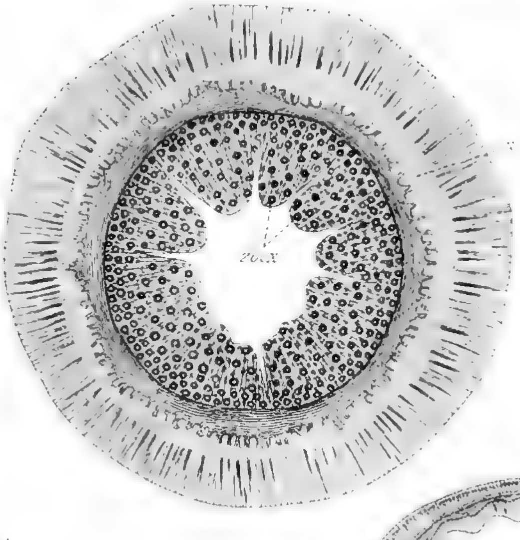

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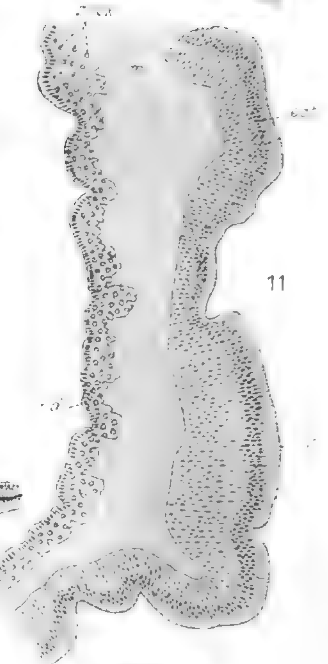

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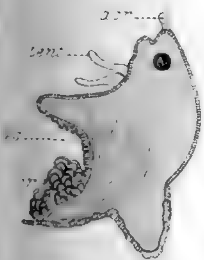

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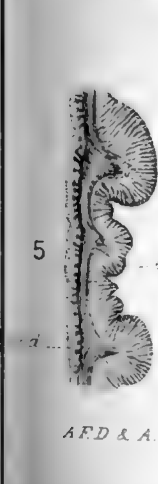

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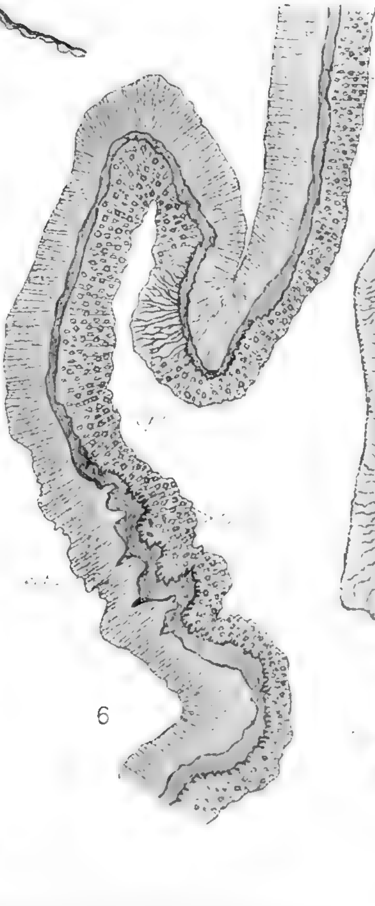

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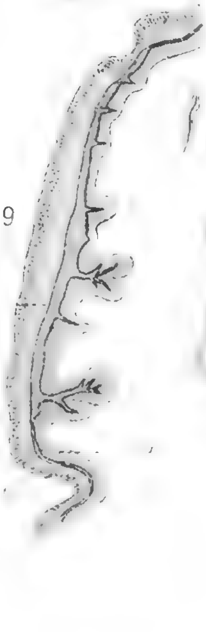

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A.F.D. & A.C.H. del.

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EXPLANATION OF PLATE XXVII.

PLATE XXVII.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Actinoides Dixoniana (H. and S.), (p. 424).

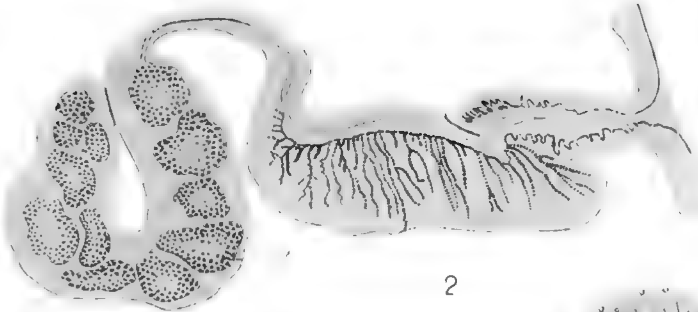
Figure.

1. Vertical section of upper portion of column with acrorhagia, sphincter, and tentacles.
2. Transverse section of a mesentery with testes.

Actinoides Papuensis, n. sp. (p. 426).

3. Vertical section of upper portion of column with acrorhagia and sphincter.
4. Transverse section of a mesentery with ova.
5. Transverse section of a specimen with two pairs of directives.
6. Transverse section of a specimen with three pairs of directives.
7. Transverse section of a specimen with four pairs of directives.


1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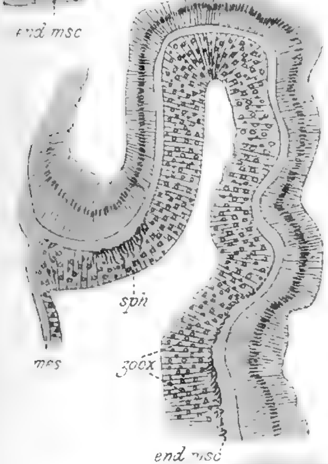
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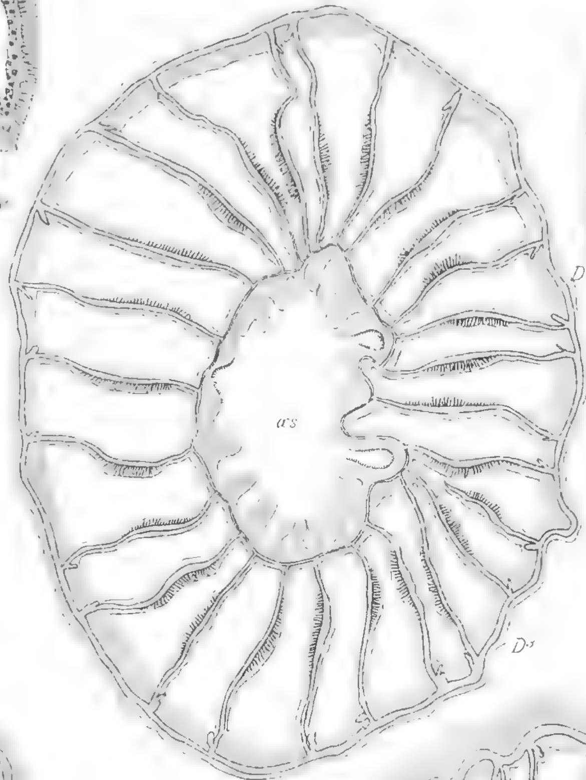
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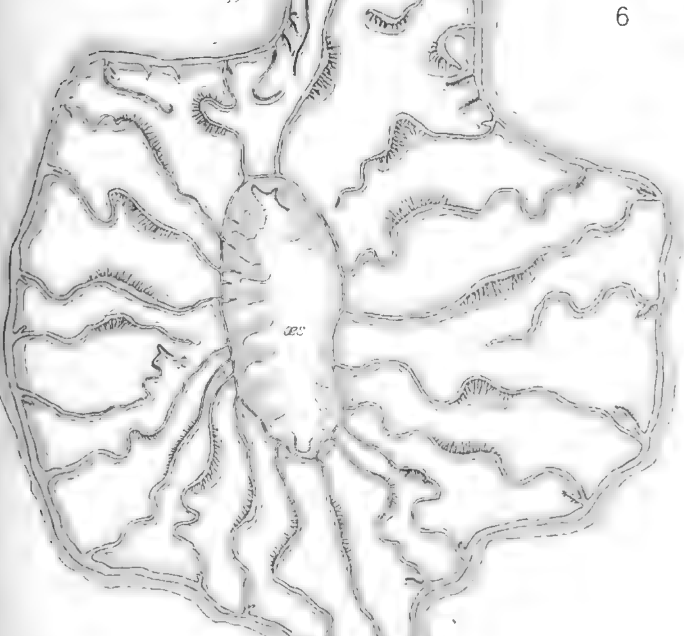
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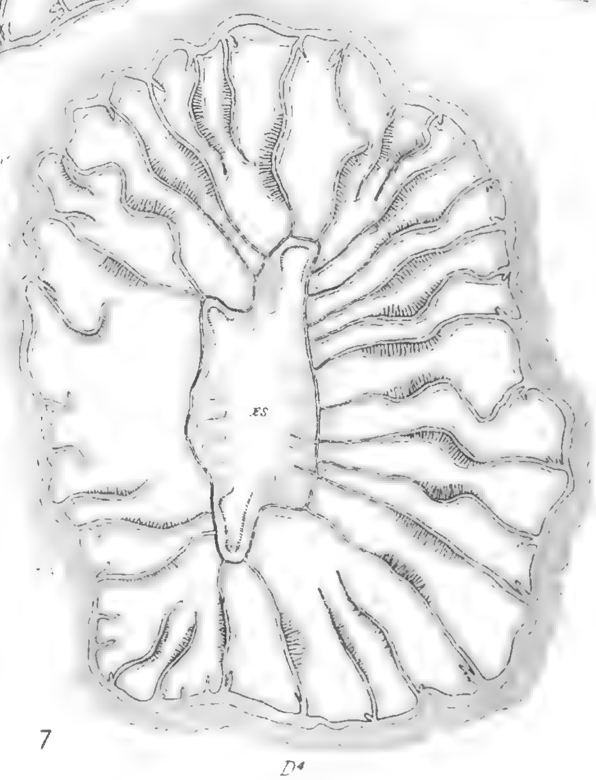
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A.M.S del.
Edwin Wilson Cambridge.

EXPLANATION OF PLATE XXVIII.

PLATE XXVIII.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Actinoides Sesere (H. and S.), (p. 428).

Figure.

1. Vertical section of upper portion of body-wall, × about 50 diam.
2. Section of the sphincter muscle, × about 100 diam.

Macrodactyla aspera (H. and S.), (p. 431).

3. Section of the sphincter muscle, × about 100 diam.
4. Vertical section of portion of the body-wall, × about 45 diam.
5. Transverse section of a portion of a mesentery, × about 14 diam.

Aulactinia Gelam (H. and S.), (p. 442).

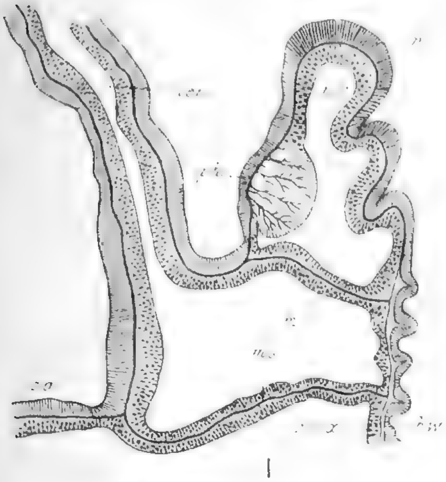
6. Section of the sphincter muscle of the specimen from Mabuiag, × 50 diam.
7. Section of the sphincter muscle of the specimen from Mer, × 25 diam.

Ixalactis simplex (H. and S.), (p. 443).

8. Vertical section of upper portion of body-wall.
9. Section of the sphincter muscle, × 100.

Phellia vermiformis, n. sp., (p. 454).

10. Vertical section of upper portion of body-wall to show the character of the sphincter muscle, × 50.
11. Transverse section through a directive mesentery at the level of the œsophagus, × 24.



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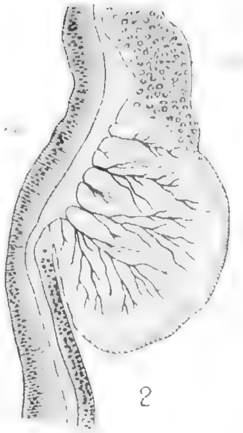

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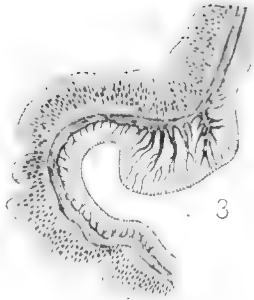

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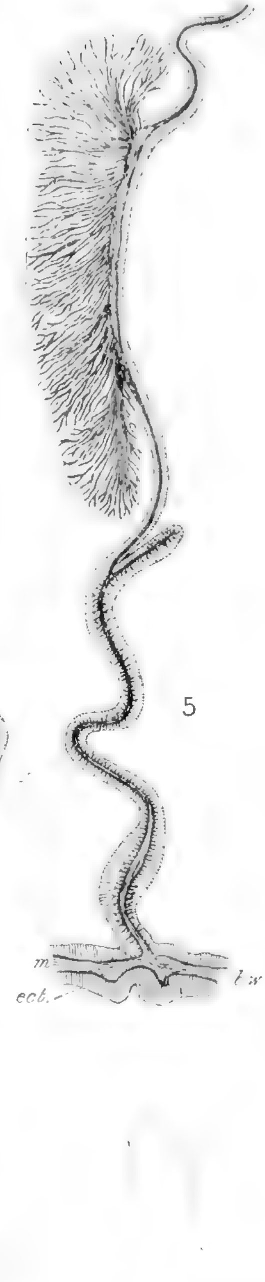

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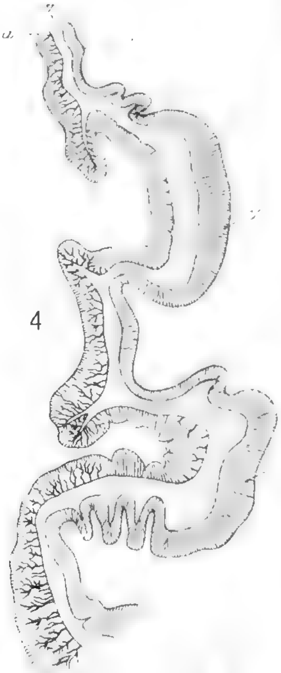

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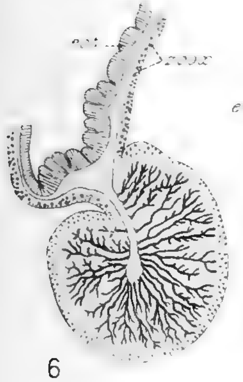

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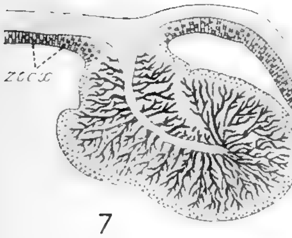

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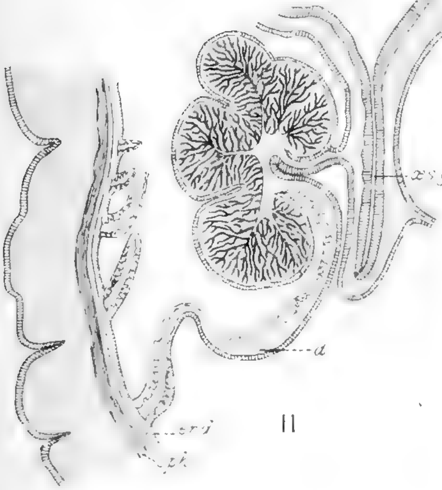

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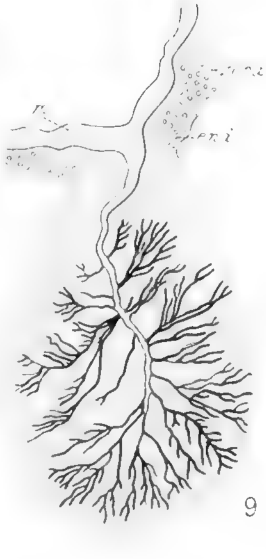

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A.C.H. del.

Edwin Wilson Cambridge

EXPLANATION OF PLATE XXIX.

PLATE XXIX.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Sagartia Milmani (H. and S.), (p. 449).

Figure.

1. Vertical section through the upper portion of the body-wall to show the sphincter muscle, × 25 diam.
2. Detail of upper (distal) portion of sphincter, × 230 diam.
3. Detail of central portion of sphincter, × 230 diam.
4. Detail of lower (proximal) portion of sphincter, × 230 diam.
5. Transverse section through a mesentery.

Paraphellia Hunti (H. and S.), (p. 461).

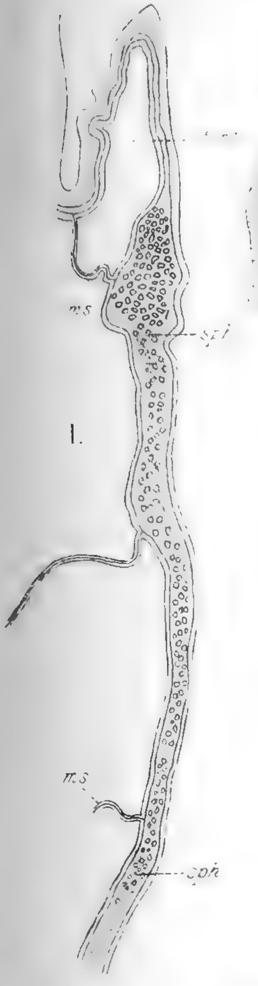
6. Vertical section through the upper portion of the body-wall to show the sphincter muscle, × 50 diam
7. Detail of upper portion of sphincter, × 230 diam.
8. Detail of lower portion of sphincter, × 230 diam.
9. Transverse section through part of a primary mesentery, × 50 diam.

Paraphellia lineata (H. and S.), (p. 462).

10. Detail of distal portion of sphincter muscle, × 230 diam.
11. Sketch of proximal portion of sphincter muscle.

Sagartia plebeia, n. sp. (p. 451).

12. Vertical section through the upper portion of the body-wall to show the sphincter muscle.



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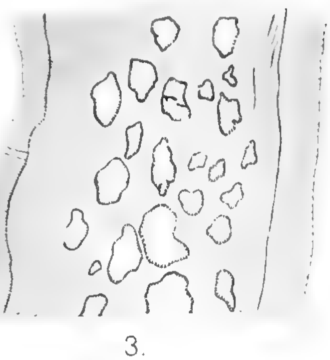

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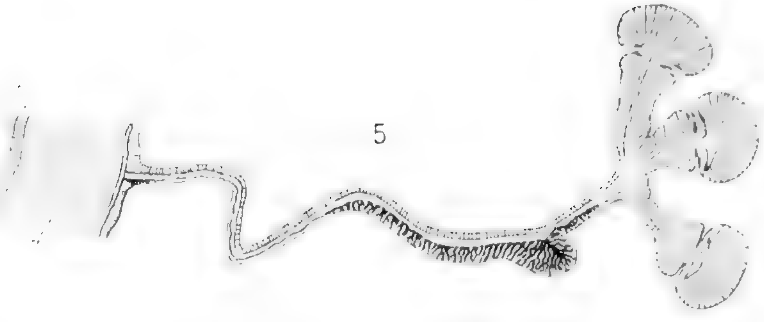

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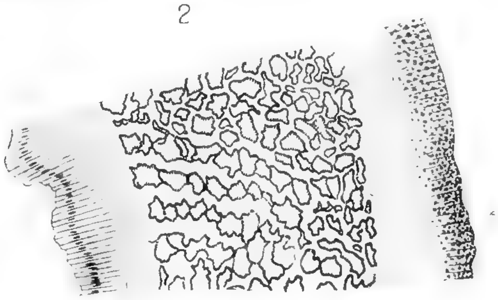

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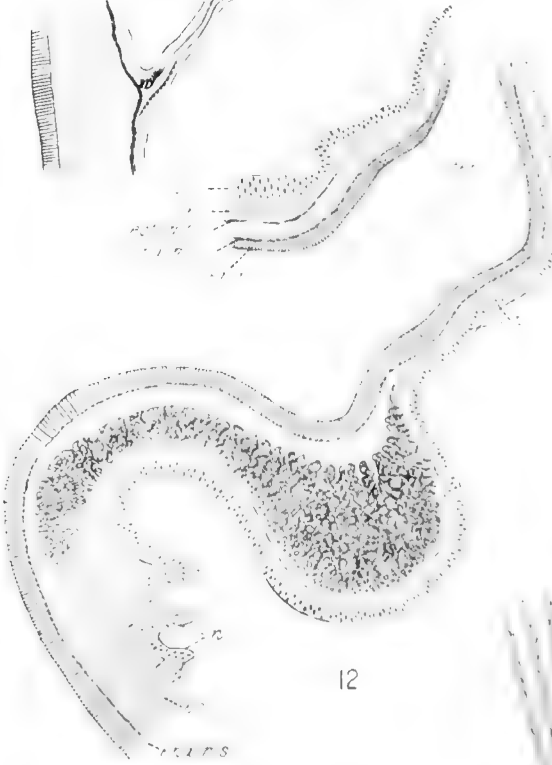

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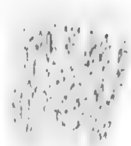

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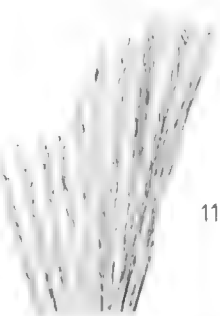

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EXPLANATION OF PLATE XXX.

PLATE XXX.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
œs.	œsophagus (stomatodæum).
œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Corynactis hoplites (H. and S.), (p 467).

Figure.

1. Transverse section of the head of a tentacle to show the nematocysts of the ectoderm, × about 450 diam.
2. Vertical section through the upper portion of the body-wall to show the sphincter muscle, × about 100 diam.
3. Semi-diagrammatic section through the œsophageal region to show the arrangement of the mesenteries, × 20 diam.
4. Transverse section through the base of a mesentery.

Stichophora torpedo (Bell), (p. 464).

5. Diagrammatic section through the œsophageal region to show the arrangement of the mesenteries, × about 3 diam.
6. Semi-diagrammatic section through the sulcular ("dorsal") region of the body in the œsophageal region, × 15 diam.
7. An imperfect, and part of a perfect, mesentery, × 50 diam.
8. Sketch of a characteristic transverse section of the retractor muscle of a mesentery, × 50 diam.
9. Vertical section through the upper portion of the body-wall to show the sphincter, × about 100 diam.
10. Sphincter muscle, × about 200 diam.
11. Mesenterial filament, × 145 diam.

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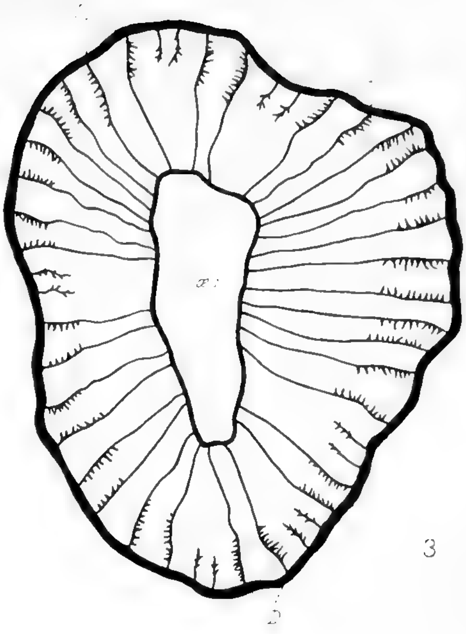

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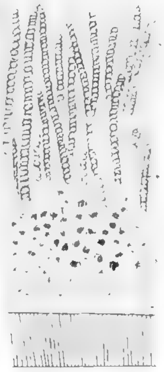

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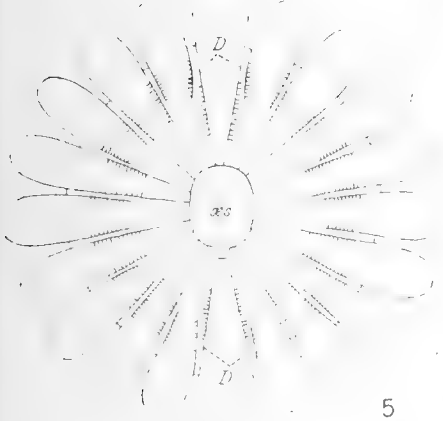

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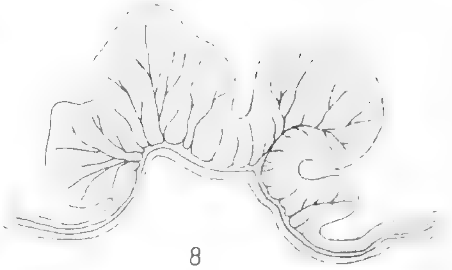

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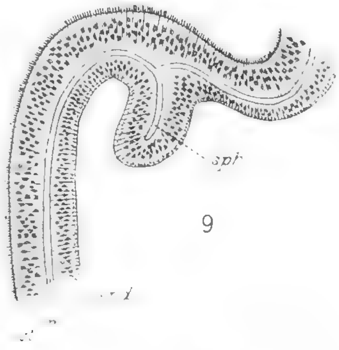

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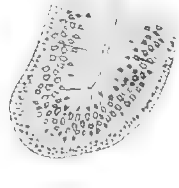

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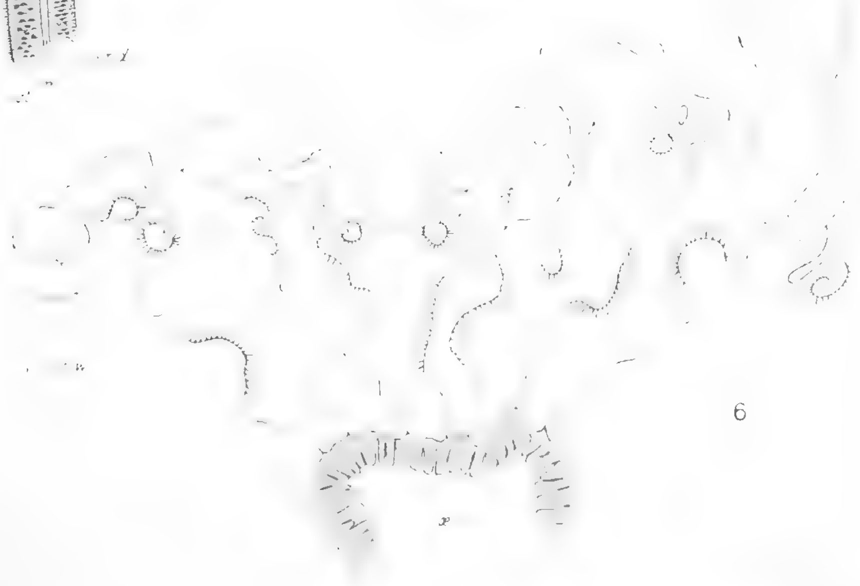

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EXPLANATION OF PLATE XXXI.

PLATE XXXI.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body-wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
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o. d.	oral disk.
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ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Radianthus macrodactylus (H. and S.), (p. 471).

Figure.

1. Vertical section through the upper portion of the body-wall to show the sphincter, × 12 diam.
2. Section through the sphincter muscle, × 50 diam.
3. Section through the sphincter muscle and a sucker (verruca), × 50 diam.

Radianthus Malu (H. and S.), (p. 472).

4. Vertical section through the upper portion of the body-wall to show the sphincter, × 15 diam.
5. Section through the sphincter muscle, × 100 diam.

Stoichactis Kenti (H. and S.), (p. 473).

6. Vertical section through the upper portion of the body-wall to show the sphincter, × 15 diam.
7. Section through the sphincter muscle, × 100 diam.

Stoichactis Haddoni (S.-K.), (p. 474).

8. Section through the sphincter muscle, × 50 diam.

Phymanthus muscosus (H. and S.), (p. 496).

9. Section through the sphincter muscle, × 100 diam.

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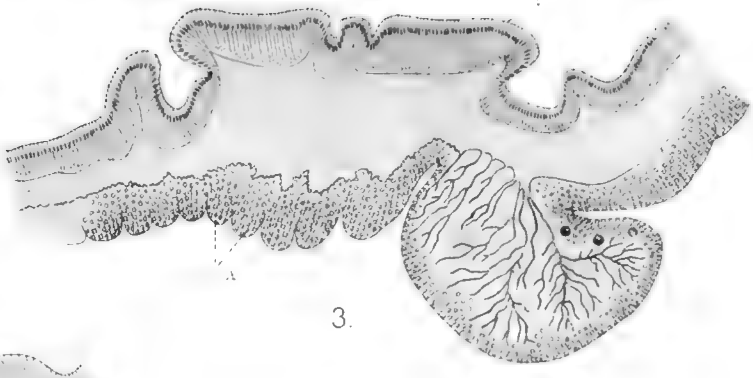

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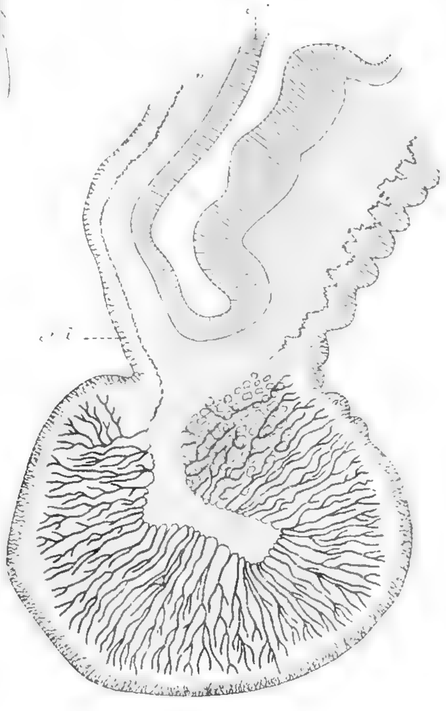

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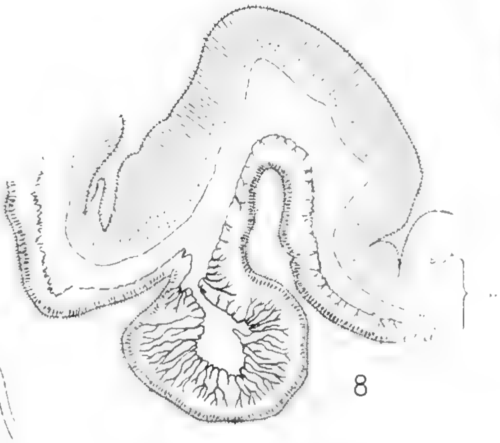

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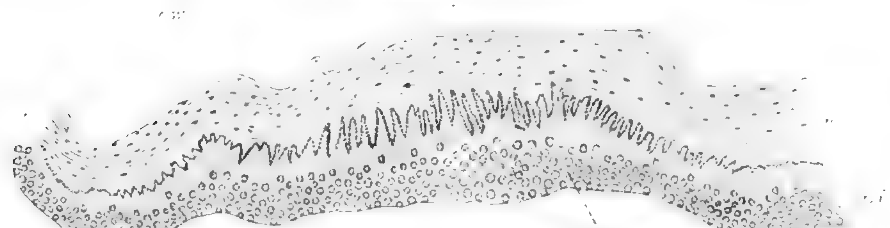

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EXPLANATION OF PLATE XXXII.

PLATE XXXII.

LETTERING ON THE FIGURES.

acr.	acrorhagia.
ad. tent.	adhesive tentacles.
b. w.	body wall.
D.	directive mesentery.
dend. tent.	dendritic tentacles.
ect.	ectoderm.
end.	endoderm.
end. msc.	muscular layer of endoderm.
g.	globular tentacles.
m.	mesoglœa.
ms.	mesentery.
n.	nematocysts.
n. l.	nervous layer of ectoderm.
o. d.	oral disk.
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œs. gr.	œsophageal groove (gonidial groove).
ov.	ovary.
p.	parapet.
periph. tent.	peripheral tentacles.
sph.	sphincter muscle.
t.	testis.
tent.	tentacle.
v.	verruca.
zoox.	zooxanthellæ.

Actineria dendrophora (H. and S.), (p. 487).

Figure.

1. Sagittal section through a lobe of the oral disk, showing the dendritic and globular tentacles, × 10 diam.
2. Sagittal section through a peripheral tentacle, × 10 diam.

3, 4. Two aspects of the sphincter muscle, × 100 diam.

Cryptodendrum adhæsivum (Klunz), (p. 483).

5. Vertical section through the upper portion of the column to show the position of the sphincter muscle, × 15 diam.
6. Section through the sphincter muscle, × 100 diam.

Actinotryx bryoides (H. and S.), (p. 479).

7. Vertical section through the upper portion of the column to show the sphincter muscle, parapet, and dendritic tentacles, × 15 diam.
8. Section through the sphincter muscle, × 75 diam.
9. Horizontal section through a portion of the oral disk, showing in the lower part of the figure the body-wall and the superior portion of the mesenterial filaments; the hollow stems of the tentacles are seen in the thick mesoglœa of the oral disk arising in a linear manner from the endocœls, × 25 diam.

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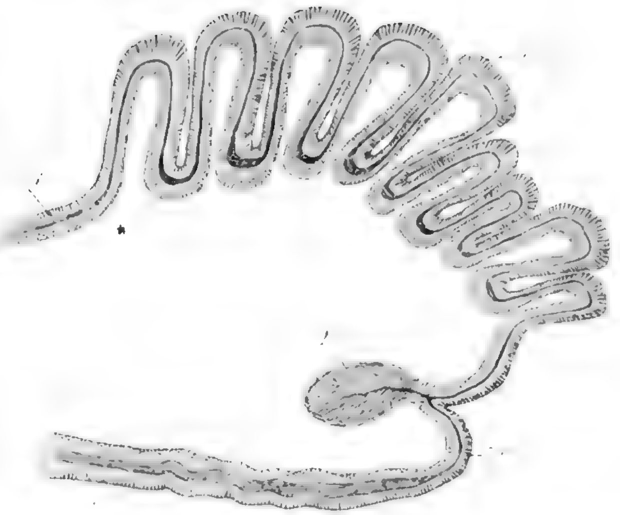

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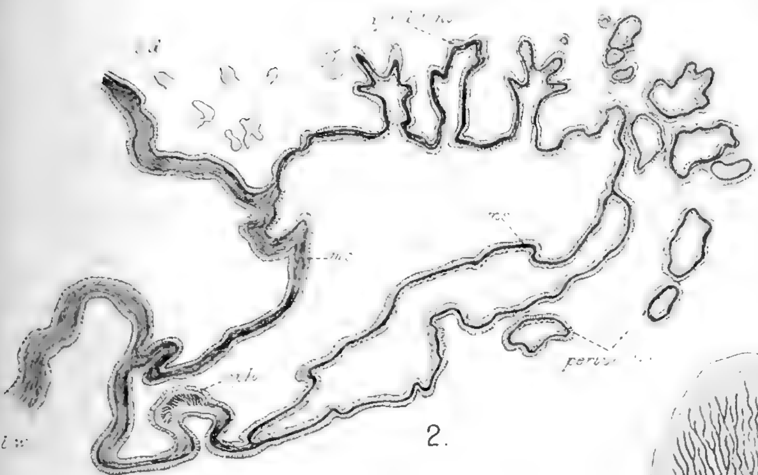

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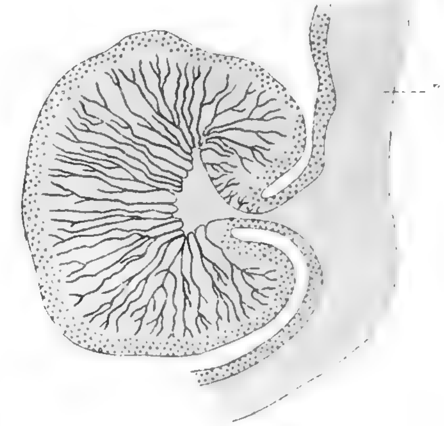

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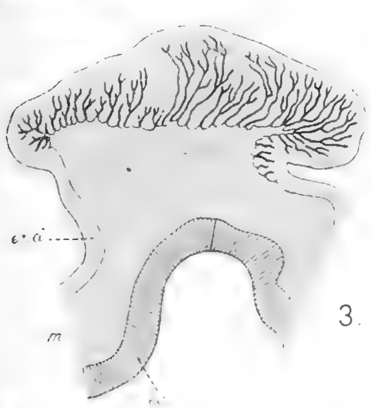

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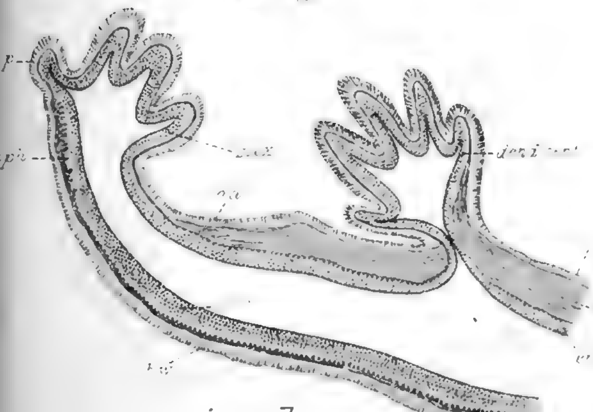

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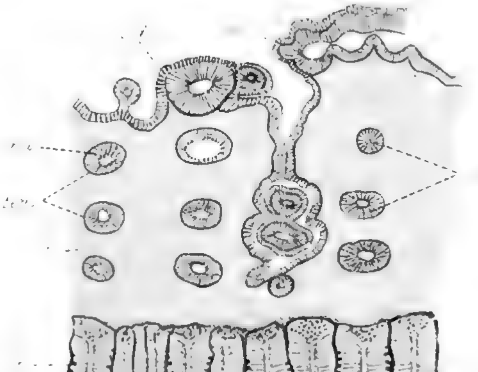

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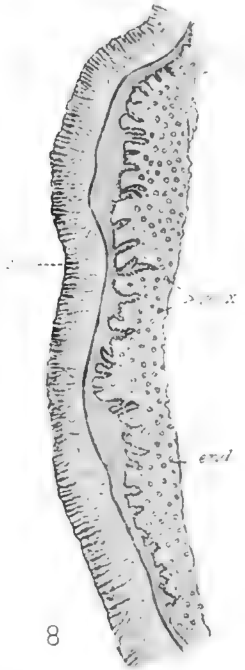

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