VI.


(Plates XXXVIII. to XLVI.)
VI.


(Plates XXXVIII. to XLVI.)

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORGATE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.
1890.
VI.


Plates XXXVIII to XLVI.

[Read April 16, 1890.]

[Communicated by Professor E. P. Wright, M.D.]

1.—INTRODUCTION.

During the year 1889 I had the pleasure, accompanied by my friend Mr. A. Smith Woodward, to visit some of the principal Museums in Sweden and Denmark, and to become personally known to those who were in charge of them. The collection of fish-remains from the chalk of South Sweden have received little attention since the time of S. Nillson, who first discovered fish remains in the Swedish chalk, and who described a few teeth in his work on the "Petrificata Suecana, formationis Cretaceæ," published in 1827. Eleven years afterwards W. Hissinger copied the plates of Nillson into his "Lethea Suecica seu Petrificata Suecæ," but does not appear to have advanced beyond his predecessor. Since that time the number of examples of fossil fishes has largely increased, and the collections are now of great interest. The present memoir is due mainly to the suggestion of Dr. Bernard Lundgren, that the enlarged collections needed, and were worthy of, renewed study; and his offer, coupled with a subsequent one by Dr. G. Lindström, to allow the specimens to be sent to England for this purpose, was a sufficient inducement to me to accept it. An application to Dr. C. Lütken for the collection at Copenhagen was also readily granted, and others followed.

I have unfeigned pleasure in expressing my great indebtedness to Dr. G. Lindström, Keeper of Palæontology, National Museum, Stockholm; to Dr. Bernard Lundgren of the University of Lund; to Professor O. Torrell, Director of the Geological Survey of Sweden; to Dr. C. Lütken, Professor of Zoology at the University of Copenhagen; to Dr. F. Johnstrup, Director of the University Mineralogical and Geological Museum at Copenhagen, and to others, for their great courtesy and kindness in unreservedly placing the collections in their charge at my disposal, and so affording me the best opportunities possible to identify and record the occurrence of the fish remains which have been found in the chalk of Scandinavia. Dr. Lütken has kindly furnished me with particulars of his own
unpublished observations on the selachian teeth found in the white chalk of Faxe and Saltholm. The opinions of an authority of so high eminence have been very valuable. The collection from the University Zoological Museum at Copenhagen contains many specimens from the original museum formed by the late King Christian VIII. I am also indebted to Dr. Johnstrup for stratigraphical information respecting the localities in Denmark. Dr. Bernard Lundgren has furnished me with a table of formations, showing also the districts in which the localities occur from which fish remains have been obtained; and a published list of the fossil fauna of Sweden. And to Dr. Lindström I am under obligation for a variety of information not easily enumerated.

Dr. Henry Woodward, keeper of the geological collections at the British Museum, has, with his usual kindness, afforded me every opportunity to compare and study the specimens under his charge with the Scandinavian ones; and to Mr. A. Smith Woodward I am indebted for suggestions and information bearing on the subject of this memoir, and for the uniform courtesy and kindness with which he has given me advice and assistance both in and out of the Museum.

The ichthyic fauna of the Swedish chalk offers several points of considerable interest. It has shown, generally, a closer relationship to the cretaceous fauna of the North of Europe, as represented in the English and French chalk, than to the more highly specialized fauna of Asia Minor; but it does not afford representatives of several of the Physostomous Teleosteans such as Ichthyodectes, Protosphyrenia, and Pachyrhizodus, which occur in the English chalk, and have been found in the Upper Cretaceous rocks of North America. A few teeth occur in the Swedish chalk which are referred to Enchodus. Examples of a large species of Dentectis occur, and some fragmentary remains which are probably Clupean. The highly specialized forms, such as Cheirothrix, Rhinellus, Spaniodon, Eurygnathus, and Eurypholis, found in the Lebanon chalk, do not occur in the chalk of Sweden. Amongst the Acanthoptyerian Teleosteans the most important are the remains of Beryx and Hoplopteryx. These genera are represented in both the English and Lebanon chalk.

The great majority of the fish remains are Selachian, and comprise no fewer than twenty-four species. Three species, viz. Carcharodon rondeletii (M. & H.), Otodus obliquus (Ag.), and Odontaspis acutissimus (Ag.), are usually regarded and known as indicating a tertiary fauna; but in the Scandinavian chalk they have been found in association with many undoubted Cretaceous forms in the Faxe limestone or chalk, and so appear to prove that these species were in existence before the advent of the deposition of the Tertiary strata. The Tectospondylic sharks* are represented by two species of Phyodus and indefinable teeth of

* C. Hassé, Das Natürliche System der Elasmobranchier, 1879–82.
Myliobatis. The Asterospondylic sharks occur in very large numbers, and represent several genera. Beautifully preserved specimens of Notidanus, Scapanorhynchus (Rhinognathus), Odontaspis, Oxyrhina, Otodus, Lamna, and Corax are abundant, and have a wide vertical range. The teeth here described as Oxyrhina lundgreni possess peculiarities which, in some respects, dissociate them from Oxyrhina, and it may be found necessary to form them into a new genus. The character and extent of the Selachian fauna indicates conditions very similar to those accompanying the deposition of the English and French chalk and that of Central Europe generally, whilst it affords comparatively little data for comparison with that of Lebanon. The occurrence of numerous teeth of Scapanorhynchus in the Swedish area is worthy of note, but the fish are not found preserved bodily as they are in the Lebanon chalk.

The classification adopted is based, as far as possible, on that of the recently-published "Catalogue of the Fossil Fishes in the British Museum (Natural History), Part I.," by Mr. A. Smith Woodward. Whilst recognising the great merits of this work, and the painstaking care with which it has been compiled and arranged, it cannot be denied that there are some portions of the re-arranged classification which are open to doubt; and, possibly, to no group of fossil fishes does this apply more forcibly than to the Lamnidae. I propose, therefore, to briefly review the most salient characteristics of the genera composing the Lamnidae, especially those found in the chalk of Scandinavia, and drawing such deductions therefrom as appear to me most reasonable.

The following genera are included in the family Lamnidae:—

Sphenodus, Agass. (Orthacodus, Smith Woodw.).
Alopecias, M. and H.
Cetorhinus, de Blainv. (Selache, Cuv., Hassè).
Carcharodon, M. and H.
Corax, Agass.
Otodus, Agass.
Oxyrhina, Agass.
Lamna, Cuvier.
Odontaspis, Agass.
Scapanorhynchus, Smith Woodw.

Sphenodus comprises four or five species, of which only the teeth are known, characterised by a wide base, with a slender median crown. All the species are found in the Jurassic rocks of the Continent, but have not been found in England. The genus Alopecias is also restricted to the Continent, and is found in the Molasse of Baltringen and the Eocene strata of Prussia.
founded on teeth and vertebrae which resemble those of *Selache (Cetorhinus) maxima*, occurs in the Tertiary strata of Antwerp, Italy, and Germany. The genus Carcharodon was established by Müller and Henle, who separated the species of this genus from those of Carcharias.* The type of the new genus was *Carcharodon rondeletii*, Müll. and Henle. The latter authors still further distinguished the two genera by the microscopical examination of their teeth. Those of the genus Carcharias were found to be hollow, whilst those of Carcharodon were solid, like those of the genera constituting the Lamnidae. The Carcharodon was therefore removed, and incorporated with the family of Lamnidae. The type of the genus is the single existing species *C. rondeletii*. The teeth of this species attain a length of an inch and a-half, and the entire length of the fish approaches forty feet. The teeth of the Tertiary representative of the genus *C. megalodon* are four or five inches in length; and if the fish was proportionally large it must have been of extraordinary size. The teeth of *C. rondeletii* exhibit considerable variety of form, but are all triangular, with serrated margins, but without lateral cones or denticles. The teeth in front on each side the symphysis of the jaws are higher in the crown and narrower at the base than those located further back; the posterior teeth gradually diminish in size, and, at the same time, become very broad in comparison to the height. The teeth of the lower jaw are more lance-like than those of the upper one, which are more uniformly triangular, with straighter margins.

The second dorsal fin and the anal are small. The lower lobe of the caudal fin is well developed, with a keel along the side, and there is a pit at its root.

Agassiz, in addition to the species of Carcharodon found fossil, which closely resembled the existing one, included in the genus a number of others which were unlike the type in possessing well-developed lateral denticles on their anterior and posterior borders. Whilst recognising the irregularity in form,† it did not appear of sufficient importance to justify the establishment of a new genus. Other species, in addition to the lateral denticles, depart still further from the type, in having the anterior border very much arched. Such species are *Carcharodon leptodon*, *C. disauris*, *C. megalotis*, *C. heterodon*, *C. auriculatus*,‡ *C. toliapicus*,§ and others. Agassiz is more specific in the statement of his opinion with respect to these species, that they ought, at some time, to be isolated with others to form a genus apart. He is confirmed in this opinion by the fact that in the living species the tendency of the teeth to assume an arched form is scarcely perceptible, whilst it is constantly seen in some other genera of Lamnidae, and in true examples of Carcharias.

---

* Syst. beschrieb. Plagiostom, p. 70. 1841.
Corax is known only by the teeth. They are sufficiently distinctive in form and of world-wide distribution. They are distinguished from the teeth of the existing Carcharias and Galeus, to which they bear considerable resemblance, by having no central cavity. The teeth of the existing fishes are hollow.

Teeth of Otodus are only known in a fossil state. The genus was instituted by Agassiz for teeth which exhibited forms intermediate between Carcharodon on the one side, and Oxyrhina and Lamna on the other. They agree with the genus Lamna in possessing lateral denticles; but whilst those of Lamna and Odontaspis are cylindrical and sharply pointed, those of Otodus are larger, flat, and blunt. The same characters may also be said to distinguish the crown of each respectively. The root of Otodus is very large and thick; but it has not the extended horn-like projections which characterize Lamna.* From Oxyrhina this genus is distinguished by the presence of the lateral denticles, and from Carcharodon it is separated by the absence of the serrated margins which characterize the former. Agassiz regards this character as of great importance, and though it may be of doubtful value in some species placed on the confines of the genera, he regards it as not less decisive in the greater number. He says, however (p. 266): “Il en est de ceci comme de toutes nos diagnoses; elles ne sont vraies que dans certaines limites, et c’est a la perspicacité du naturaliste à reconnaître et à sentir où ces limites se trouvent.” The microscopical structure of the teeth is solid and massive, as in Carcharodon and the true Lamna. The genus appears first in the Cretaceous rocks, was abundant in the Tertiaries, and died out before the existing period.

The genus Oxyrhina includes one or two existing species. The type of the genus, and the one best known, is Oxyrhina spallanzani (Lamna ozyrhina, Cuv. and Val.). The teeth are completely free from lateral denticles, and the margins are smooth. The crown of the tooth is very similar in form to that of Otodus; and imperfectly-preserved specimens of Otodus, from which the base has been broken so as to detach the lateral denticles, can with difficulty be distinguished from Oxyrhina. The fossil teeth attain a considerable size; they conform generally with the ordinary arrangement of the teeth in sharks; those situated on the anterior part of the jaws are more lanceolate and acutely pointed than those occupying a median position, whilst the posterior teeth are smaller, triangular, and much compressed.

The genus Lamna was originally founded by Cuvier;† and embraced a variety of fishes which have since been taken as the types of other genera, amongst them Otodus, Carcharodon, and Oxyrhina, characterized by the form of the teeth. Of the existing sharks, Lamna cornubica, Cuv., may be taken as the type of the genus.

Müller and Henle, amongst other characters of the genus, give:* "the second dorsal and anal small of equal dimensions, opposite; pit at base of caudal distinct, a keel along each side of the tail." These characters apply equally to Oxyrhina and Carcharodon; Odontaspis is distinguished by the second dorsal and anal fins being large; having no pit at the root of the tail, and the absence of keels along the lateral surface. In all three genera the branchial arches are large and situated in front of the pectoral fin. All the characters on which Müller and Henle based their classification are external, and pertaining to parts of the body which are not usually found in a fossil state, and the palæontologist, as Agassiz points out,† sees with regret that no account whatever is taken of the skeleton or the dentition; and it is a remarkable coincidence, that the teeth which present the nearest resemblance, viz. those of Lamna and Odontaspis, should be distinctly removed by the external form of the caudal fin, and by the position and size of the dorsal and anal fins to separate genera; whilst Cetorhinus, Blain. (Selache, Cuv.), Oxyrhina, Agass., and Carcharodon, Müller and Henle, which have teeth of such great dissimilarity to Lamna, are grouped in the same family in close relationship with that genus.

The teeth of Lamna cornubica, Cuv., are more or less varied in form in different parts of the jaws; they may be described as possessing a high, median, cone-shaped crown, flat, and compressed antero-posteriorly, with smooth margins; a single lateral denticle exists on each side of the median cone. The median cone approaches to that of Otodus in form on the one side, but the lateral cones are smaller and more acuminate; and on the other, it possesses much resemblance to some of the teeth of Odontaspis. It is principally distinguished by the cylindrical, and often twisted form of Odontaspis, which has also longer and more pointed lateral denticles. In Lamna the lateral denticles do not number more than one on each side, but in Odontaspis there are frequently two, and occasionally three on each side. The number is, however, inconstant, and even the teeth of the same fish sometimes are variable. Agassiz very forcibly remarks that the variation observed in the number of the lateral denticles is not calculated to inspire a great amount of confidence in their value for determining genera.

The teeth of Lamna are readily distinguished from those of Oxyrhina, if the base of the tooth and the root are well preserved, because Oxyrhina has no lateral denticles; from those of Otodus they are less readily distinguished, and some intermediate species appear to bridge over the limits between the two genera, such for example as Otodus appendiculatus, one of the most common forms, which can scarcely be distinguished from some of the Lamna.

Some of the characters of Odontaspis have already been enumerated. The

---

* Systematische Beschreibung der Plagiostomen, p. 66.  
† Poiss. Foss., vol. iii., p. 287.
genus is represented by species still existing. In one of them, *Odontaspis ferox*, Agass., all the teeth except those situated most posteriorly, have a high, narrow, pointed crown, on each side of which are two, sometimes three, rounded and acuminate denticles. Both these and the median cone are more or less cylindrical, and usually exhibit a sygmoideal curvature. The teeth of both the upper and lower jaw are similar in form; on each side of the symphysis there is a small pointed tooth, succeeded by much larger ones, narrow at the base as compared with the height of the crown. In the upper jaw between the second and third large tooth, the fourth and succeeding ones from the symphysis, there are four teeth, very small, about one-third the height of the large front teeth. After these are larger ones, broader at the base, all with acuminate crowns, and diminishing in size backwards. In the lower jaw the intermediate small teeth do not occur, but the teeth gradually diminish in height and size backwards. All are possessed of two lateral denticles on each margin of the teeth. Agassiz* did not consider that the teeth of *Odontaspis* were separated with sufficient distinctness from *Lamna* to warrant him in forming a new genus; but the teeth found fossil which approached the living *Odontaspis*, he indicated by placing the word in a parenthesis.

Another genus of the Lamnidae occurs in the chalk of Mount Lebanon, and was described by the writer† as Rhinognathus. It forms one of a very few instances in which the body of a Lamnoid fish with teeth in the natural position have been found fossil. It is distinguished from existing genera by the length of the anal fin. The body is long, and the snout much elongated, and more or less spatulate. The teeth are long and acuminate, with a pair of small lateral denticles in the anterior part of the jaws, broader and shorter behind. The teeth are not readily distinguishable from those of *Odontaspis*; and the broader ones are not unlike some of the species of *Lamna*. Mr. A. Smith Woodward‡ has pointed out that the generic name Rhinognathus was pre-occupied by Fairmaire in 1873, and has suggested Scapanorhynchus in its stead.§

In addition to the species from Lebanon, Mr. Woodward has included under this genus several species described by authors as *Lamna* and *Odontaspis*. Dr. H. E. Sauvage|| in 1872 described a number of fish remains from the Cretaceous rocks of Sarthe, and amongst others, species of the genera *Oxyrhina*, *Otodus*, *Lamna*, and *Odontaspis*. Agreeing with Agassiz in the diagnosis of

---

§ The inference drawn by Mr. Woodward that this genus was considered as one of the Spinacidae is incorrect. The omission of a line after the description of the preceding species may have led to the error.
Oxyrhina, he observes that in the young stages of Lamna the teeth are without lateral denticles, and that these only develop later. Of the genus Otodus, he remarks that it is closely allied with Lamna, from which it only differs in the greater development of the lateral denticles, their broader and less slender form. The teeth of Otodus, whilst having the form of those of Carcharodon, are not serrated on the margins, but in the opinion of M. Sauvage the three genera named are closely related. He quotes an observation of M. Pictet, that these teeth in many instances vary more from different parts of the same mouth than their homologues in another species, and that this variation renders the difficulty of the interpretation of their exact specific characters very great. This observation applies with considerable force to the genera Lamna and Odontaspis, the teeth of which closely resemble each other; but the fishes still existing enable the naturalist to study and compare them, and their relationship is far more distant than some of the other genera whose teeth have less resemblance. Paleontologically it is very difficult to separate the two genera, which are quite distinct in living examples.

In the year 1854 Valerian Kiprijanoff described a number of Selachian teeth from the Cenomanian ferruginous sandstones of the governments of Kursk and Orel, in Russia.* The characteristics of the teeth of the genera before named, as defined by Agassiz, are cited; [the difficulty of determining fragmentary examples is stated to be almost insurmountable, and the microscopical examination of the structure of the crown of Otodus, Lamna, and Oxyrhina is found to afford no definite characteristics. The description of several species of Otodus, led the author to seek the relationship of the genus with other associated forms, and he expressed the opinion founded on his investigation, that the broad teeth approach most nearly to Carcharodon, whilst towards the opposite extreme their similarity to the teeth of Lamna stand out clearly. Specimens without lateral denticles are indistinguishable from the teeth of Oxyrhina. Kiprijanoff states that in young examples the teeth of Odontaspis possess lateral denticles at an earlier stage than do those of Lamna; and he regrets that an example of the jaw of Otodus has not been found, so that some information as to the arrangement of the teeth in situ might be obtained.

Professor Zittel† accepts the general definition of the genera of the Lamnidae, and cites the opinion of C. Hassè‡ that the Lamnidae have developed from the Scylliolamnidae, with which they are nearly connected, especially through the

† Handbuch der Paleontologie von Karl A. Zittel, band iii., p. 81. 1887.
‡ Das Natürliche system der Elasmobranchier von C. Hassè; 1879: see Stammtafel 1.
genus Otodus; at the same time, regarding Otodus as a connecting link between the two families, he considers that it is so close to the typical Lamnidae that it is difficult to draw a line to divide them.

Perhaps the most recent contribution to the subject is by A. Smith Woodward in the Catalogue of the Fossil Fishes in the British Museum.* The great bulk of the teeth of Lamna, previously described, are transferred to the genus Odontaspis, and those of Otodus to the genus Lamna; Otodus, except as a synonym, dropping out of the vocabulary. The Lebanon genus Rhinognathus renamed Scaphanorhynchus is accepted, and included with it are some of the species of Lamna (Odontaspis) described by Agassiz. Oxyrhina is retained without alteration, and the teeth are defined as without denticles, but it is stated on another page that some of the teeth of this genus have minute denticles. Woodward is of opinion that “although only differing from Lamna in the prevailing absence of lateral denticles in the teeth, it is convenient from a palæontological point of view to retain Oxyrhina as a distinct genus, more especially as several forms of these teeth bear specific names identical with those referable to Lamna proper.” Lamna acuminata, Agassiz †, is included as a synonym of Oxyrhina mantelli, Agass., apparently on the authority of Sauvage, but that author ‡ is doubtful whether the teeth, figs. 55, 56, 57, are referable to L. acuminata, but has no doubt about fig. 54, which he accepts as the type of the species. If this view be correct, the tooth represented by fig. 54, Woodward, to be consistent, should have included in his genus Odontaspis; the presence of well-formed lateral denticles clearly indicates that genus. Carcharodon remains unchanged as a genus, but the species are re-distributed.

Sauvage § in the memoir already cited, points out that M. Reuss ¶ has given a figure of a tooth with feeble denticles, which that author considered to be an example of Oxyrhina mantelli, Ag. Sauvage, however, gives reasons for believing that the determination of Reuss is erroneous, and that the tooth ought be classed with Otodus oxyrhinoides, Sauvage. It is probable that an equally careful examination of other examples of teeth which possess evidence of lateral denticles, would prove that they ought not to be considered as pertaining to Oxyrhina, although they may have been found associated with undoubted teeth of that genus, and described with them.

Having thus briefly indicated the genera included in the family of the Lamnidae, it is proposed to sum up the evidence, and if possible arrive at some reasonable view for the classification of a group of fish-remains which are perhaps as per-

* Part i., p. 349, et seq.
† Poiss. Foss., vol. iii., p. 292, pl. xxxvii.α, fig. 54 († non figs. 55, 57).
‡ Poiss. Foss. de la Sarthe, p. 35.
¶ Verst. der Böhm. Kreid., 1845, pl. iii., fig. 6.
plexing as any in the whole range of palæontological science. The most profitable method of investigating fossil remains is by comparison with existing forms, and it is fortunate that all the genera are not yet extinct; and though the fossil forms far outnumber the existing ones, there are still examples of Carcharodon, Lamna, Oxyrhina, and Odontaspis. As already observed the characters of the first three existing genera as defined by Müller and Henle, having reference to the size, form, and position of the fins and tail, are identical, and so far as those tests are concerned do not indicate any generic differences. Odontaspis, on the other hand, differs from those named, in the form and position of the fins and tail, to such an extent as to induce Sauvage to place it as a separate family; whilst, judging from the teeth alone, Agassiz and others have regarded them as at most a sub-genus of Lamna. After carefully considering the divisions of the Lamnidae attempted by Müller and Henle, Agassiz expresses the opinion that they may be tangible enough, and very serviceable in existing forms, when the whole of the structure of the fish may be studied, but of little use when considering and attempting to decipher a mass of detached fragments, in nearly all cases consisting of isolated teeth or vertebrae.

The Cretaceous fish-remains, Agassiz says, are characterized by a large number of new types which have not existed at an earlier period. The group of teeth with crenulated margins appears for the first time; and amongst the smooth teeth are several types equally new, such as Otodus, Oxyrhina, and the subulate Lamna, or Odontaspis. The greatest difficulty consists in distinguishing between Otodus and Oxyrhina; and between Otodus and certain forms of Lamna; also, it is necessary in certain cases to renounce the hope of rigorously determining fragments of teeth deprived of their roots. The difficulties which encompassed Agassiz have increased since he wrote; and the discovery of numerous forms in all parts of the world, and the accumulation of large collections of fish-remains in public and private museums, have only served to produce a still more complicated result and render still more difficult a satisfactory system of classification.

The existing Lamnidae as represented in Carcharodon and Oxyrhina indicate two distinct forms of dentition both free from lateral denticles, the former with serrated anterior and posterior margins, and the latter with those margins devoid of serrations. These are abundant in the Tertiary strata, and Oxyrhina also in the Cretaceous.

Agassiz held the opinion that the serrated margin of the teeth was of generic importance, and this led him to include a number of forms with well-developed lateral denticles in the genus Carcharodon because they had serrated margins. The question immediately arises whether the serrated margin, or the presence of secondary cones is of greater generic importance. So far as the evidence of the existing species goes, there is no trace of lateral cones or denticles, and if
C. rondeletii be taken as the type, then it becomes anomalous to include in the genus such forms as *Carcharodon heterodon*, Ag., *C. megalotis*, Ag., *C. auriculatus*, Ag., *C. angustidens*, Ag., and others. In form and size they approach very nearly to some of the larger species of *Otodus*, such as *O. obliquus*, Ag., and if the margins of the latter were serrated would be indistinguishable from it.

Noetling has already suggested that *Otodus* should be joined to *Carcharodon*; but it appears much more reasonable, either that the forms associated with *Carcharodon* which possess lateral denticles should be considered as species of *Otodus*, or regarded as a separate genus.

Having regard to the remaining genera Lamna, *Otodus*, and *Odontaspis*, existing species of the first and last still survive; but unfortunately, hitherto, no specimen of a living *Otodus* has been discovered, but so many wonderful types have been found by deep sea dredging and more careful search, during the past few years, that it may not be impossible that still others may be brought to light. At any rate, until more reliable information is accessible, it may best serve the purpose of the paleontologist to regard the dismembered fragments simply as "forms" exhibiting certain tendencies of a more or less definite character. Sufficient has already been advanced to show that any lines of absolute demarcation into genera, it might almost be said species, is impossible; and the researches of every fresh student may lead to new opinions formulated in new varieties of nomenclature. Already the subject is almost hopelessly confounded; the transposition of species is bewildering; and after all there is no firm basis on which to build up a natural classification.

One of the principal difficulties appears to be, that it should be desired to make an extremely large series of fossils, representing an enormous development of the Selachians, fit to a minimized series of living representatives which are rapidly dying out; and that sufficient credit is not given to the variety and number of the species which obtained during the ascendancy of the family. Accepting this view it may be advisable to regard the teeth, as already suggested, as "forms" representing members of the family, and classify them accordingly; and it scarcely seems necessary to suggest that the successive redistribution of species amongst existing, or newly devised genera, is to be deprecated. The genera as defined by Agassiz embrace already a wide range of species, and have, hitherto, proved adequate. They are universally known and accepted, and have tolerably well-defined limits. Taking as types, *Otodus obliquus*, and the existing species *Lamna cornubica*, and *Odontaspis ferox*, the paleontologist will be able to group the ever-varying fossil forms around these centres, and though they may possess characters expressing relationship with more than one species, succeeding discoveries may show that these only express the connecting links of an unbroken line of evolitional development.
II.—CLASSIFIED DESCRIPTION OF THE FOSSIL FISH.

Class.—PISCES.
Sub-Class.—ELASMOBRANCHII.
Order.—Selachii.
Sub-Order.—Tectospondyl.
Family.—**Myliobatidæ**.


Head free from the disk; so-called cephalic fin single. Teeth large, flat, hexangular, tesselated, arranged in seven antero-posterior series. The dentition of the upper jaw strongly arched antero-posteriorly, that of the lower jaw quite flat. Dental crown smooth, or slightly striated; attached surface of root longitudinally rigid and grooved. Except in very young individuals, in which the teeth are all approximately of equal size, the median row is relatively very broad, while the teeth of the three lateral series on each side are rarely broader than long. Tail with a dorsal fin near its root, generally with a posteriorly-situated barbed spine.

*Myliobatis, sp.?*

Fragments of the teeth of this genus occur in the collection of the University of Lund. The coronal surface is smooth, and presents a somewhat reticulated appearance, due to the attrition of the upper extremities of the descending nutritive canals. The root, composed of coarse lamellæ, is smaller than the crown, and is separated from it by a concave depression of the posterior surface, the root projecting beyond the crown; on the anterior surface the reverse happens, the surface of the crown extending beyond the root.

The specimens are fragmentary, and of too indefinite a character to determine the species.

*Ex coll.*—Geological collection, University of Lund.


Teeth quadrate in form, with elevated crown, somewhat overhanging, and sharply separated from the root by a constriction. The crown is enamelled, and ornamented with large transverse or radiating ridges, surrounded by a more finely-marked marginal area of greater or less extent. The surface of attachment of root is smooth. In one jaw, presumably the lower, the median series of teeth is the largest, and the lateral rows are arranged symmetrically, diminishing in size to the left and right. In the opposing dentition the median series is very small, and the first lateral row on each side large, with the outer lateral series successively diminishing in size. The vertebrae are very deep compared with their length, complete, and apparently cyclopondylic in structure.

The well-known teeth of Ptychodus were supposed by Mantell * to have formed the dental armature of a teleostean fish nearly allied with the Diodon. The observations of Agassiz,† and the microscopical investigations of Owen,‡ led to the conclusion that the arrangement of the teeth of Ptychodus closely resembled that of the Cestraciont sharks. The absence of any specimens showing the teeth in actual position has led to a general acceptance of the view enunciated by Agassiz. More recently, Cope,§ in America, and Smith Woodward,|| in this country, have been able, by the discovery of more perfect specimens, to arrive at conclusions of great importance. Cope demonstrated that the spinous processes supposed to have been the dorsal spines of Ptychodus were the fin-rays of a Teleostean fish; and Woodward has shown that the teeth have no agreement with the dental arrangement in the Cestraciont shark, but that the dentition is that of a true ray. The arrangement of the teeth is in parallel rows, crossing the rami at right angles. There is a median row in each jaw, and on either side of it there are series placed symmetrically right and left. In the upper jaw the median teeth are small; the largest are placed in the first lateral series, from which there is a gradual diminution in size outwards. In the lower jaw the median teeth form

* Fossils of the South Downs, p. 231. 1822.
the largest row, fitting into the central groove of the opposing dentition, and on either side the teeth of the lateral series become successively smaller.*

Professor E. D. Cope † has discovered an interesting series of teeth in the uppermost Cretaceous beds of Maria Farinha, which apparently occupies a position intermediate between Ptychodorus and the living ray, Myliobatis, and which he has named Apocopodon. The teeth are covered with a thick layer of enamel, which is ridged antero-posteriorly. The median teeth are shorter than Myliobatis, and differ from both that genus and also Zygobatis in being exactly parallelogrammic in outline, the extremities being truncated instead of angulated, as in those genera. It may also be noted, that some of the Eocene Myliobatidæ possess teeth which approach more or less closely to the form of Ptychodorus. A species described by Leidy ‡ from the phosphate beds of North Carolina as *Myliobatis jugosus*, may be taken as an illustration. Professor W. Dames § has also described detached teeth from the Tuffkrede of Maastricht which appear to possess characteristics indicating an intermediate position between Ptychodorus and Myliobatis, and so forming a sort of connecting link. The teeth are named by Dames *Rhomodus binkhorstii*. The occurrence of these intermediate forms in various and widely separated parts of the world may indicate that the Ptychodonts were the antecedent types of the Myliobatidæ; and they certainly assist in confirming the results of Smith Woodward’s researches.

_Ptychodorus decurrens, Agassiz._

_(Pl. xxxviii., figs. 1, 2.)_


_Ptychodorus decurrens._ Agassiz, L., 1839. “Poiss. Foss.;” vol. iii., p. 154, pl. xxv. b, figs. 1, 2, 4, 6–8 (non 3, 5).


Ptychodus decurrens. Dixon, F., 1850. "Foss. Sussex," p. 362, pl. xxx., figs. 7, 8; pl. xxxi., fig. 1; pl. xxxii., fig. 5.

Represented by teeth from the soft white chalk of Annetorp and Oretorp in the palæontological collection of the Riksmuseum at Stockholm. The larger tooth is probably from the first lateral series of the upper jaw;† it measures 0·02 m. across, and has a length antero-posteriorly of 0·017 m.; nine ridges are exposed, extending across the crown in nearly straight lines; on each side they bifurcate, and split up into a number of minute corrugations along the margins. The nine ridges occupy an area of the surface of 0·012 m., the remaining portion being covered with ramifying ridges increasing in number towards the margin. The crown of the tooth is slightly convex. The root is buried in matrix.

* A doubtful tooth, subsequently assigned to P. oweni, Kiprijanoff, loc. cit., pt. ii., p. 2. 1881.
The second specimen is from Oretorp; less than half the size of the one described. The surface of the crown is flat, and exhibits a slight obliquity. Its location appears to have been in one of the series near the lateral extremity of the upper jaw. There are six transverse ridges, in form more or less semicircular, which occupy nearly the whole of the crown. The space occupied by the marginal corrugations is not large, but the characteristic folds extending from the central portion to the periphery are quite distinct.

Formation and Locality.—Etage Danien; Annetorp, District of Malmö, Oretorp.

Ex coll.—Riksmuseum, Stockholm.

Ptychodus mammillaris, Agassiz.

(Pl. xxxviii., fig. 3.)

Ptychodus mammillaris. Agassiz, L., 1839. "Poiss. Foss.,” vol. iii., p. 151, pl. xxv. b, figs. 12–20 (? fig. 11).
Ptychodus altior. Agassiz, L., 1839. Tom. cit., p. 155, pl. xxv. b, figs. 9, 10.


The occurrence of Ptychodus mammillaris is not common. The specimen figured is from the white chalk of Annetorp. It is very high in the crown, with ten or twelve transverse ridges extending across the somewhat narrow surface. The diameter of the base is 0.015 m., equal to the height of the crown. Below the coronal surface the sides are depressed, and covered with more or less concentric granulated striae; still lower the sides again expand, and the base is prominent, and covered with fine vertical striations.

Formation and Locality.—Etage Danien: Annetorp, District of Malmö.

Ex coll.—Riksmuseum, Stockholm.

Sub-Order.—Asteropectidæ.

Family.—Notidanidæ.


Body moderately elongated; one dorsal fin opposite to the space between the ventral and anal fins; caudal fin large, without pit at the root; mouth inferior; gill-openings—six or seven—without flaps of skin; spiracles small, on the side of the neck. Notochord persistent. Principal teeth consisting of a series of compressed cusps, fixed upon a long base, the anterior cusp larger than the others, with or without small denticles at its base in front. Anterior teeth of the upper jaw clustered, awl-shaped; a median symphysial series in the lower jaw. Principal teeth of the upper jaw less laterally elongated, with fewer cusps than those of the lower jaw.
Notidanus microdon, Agassiz.

(Pl. xxxviii., figs. 4—7.)


Teeth of this genus occur in the collections from Lund. They are in the hard cherty chalk from Malmström. Of the three specimens two are from the upper jaw, and one from the lower. Of the former the most perfect is 0·012 m. in length along the base of the crown. The crown consists of four cones or denticles; the largest is 0·005 m. in height, and on its anterior margin is a series of four or five serrations; the posterior denticles are much less elongated as compared with the principal one; all are sharply pointed. The root is large, and equal in depth to the height of the largest cone; the external surface of the root is concave; the internal surface prominent near the base of the crown,retreating lower down, so that it forms, with the external surface, a very acute angle.

The second upper tooth is somewhat smaller, and is probably from a position
further back in the jaw. The principal cone is not relatively so much larger than those behind, as it is in the example already mentioned.

The tooth from the lower jaw is smaller than those from the upper, but exquisitely preserved. It is 0.010 m. in length. There is a series of nine cones diminishing gradually and uniformly from the principal one backwards. On the anterior margin of the first cone is a number of minute serrations. The root is deeper than the height of the longest cone, large and massive.

In the collection from the Zoological museum at Copenhagen specimens of *N. microdon* are preserved which have been obtained from the Nyere Kridt at Stevns, in Denmark; from Terkild-Skov, in the Island of Seeland; and in this museum, and also in the museum of the Geological Survey, there are numerous specimens, mostly fragmentary, from the coraline chalk of Faxe. The average size of the teeth from Faxe is much larger than those from the cherty chalk. The first denticle is proportionally not so high as compared with the succeeding ones as it is in the teeth of the upper jaw, already described, and the denticles have generally a more erect appearance.

A single representative of this species occurs in the collection of fishes from the Riksmuseum of Stockholm. The specimen is 0.007 m. in length; the crown consists of seven cones, each sharply pointed, slightly curved backwards, and diminishing in size from the anterior principal one. The first cone is 0.002 m. across the base, and 0.003 m. in height along the anterior border. The latter is provided along its lower half with a series of minute but well-marked denticulations. The root is not well preserved. Fragments appear to indicate that its depth was about equal to the height of the crown. This example is from the chalk of Limhamn, in the district of Malmö, in South Sweden.

*Formation and Locality.*—Etage Danien: Malmström; Stevns, in Denmark; Terkild-Skov, in the Island of Seeland; Limhamn, in the District of Malmö; and the coraline chalk of Faxe.

*Ex coll.*—Riksmuseum, Stockholm; Zoological Museum, Copenhagen; University Museum, Lund; Mineralogical Museum, University of Copenhagen.
Notidanus dentatus, A. S. Woodward.

(Pl. xxxviii., fig. 8.)


A single example of this species is preserved in the University’s Mineralogical Museum at Copenhagen. It is a tooth of the lower jaw, and is, unfortunately, imperfect. Sufficient of the tooth is preserved to render its identification certain. The part preserved consists of the principal cone, and a second, smaller one, behind; whilst in front are six denticles; the length of the base of the crown is 0·02 m.; the height of the principal cone is 0·011 m., that of the second one is 0·008 m.; both are arched backwards. The denticles diminish gradually in size forwards. They, like the cones, are robust, rounded at the point, and whilst more or less curved backwards, are more erect than the cones. The root is not preserved.

The presence of denticles in the place of the ordinary serrated anterior margin of the tooth serves readily to distinguish this species. The original description by Smith Woodward was of teeth contained in a collection sent in 1876 to the British Museum by Sir James Hector, collected at Amuri Bluff in New Zealand. The single example of the teeth of the lower jaw possessed only three denticles on the anterior surface, and there were three additional cones behind the principal one. When describing the fossil fish remains of the Cretaceous-Tertiary formations of New Zealand, I was indebted to Sir James Hector for the loan of the Geological Survey collection from the Wellington Museum, which contained additional and better preserved specimens than those previously described. The characteristic denticles in front of the principal cone were found to reach five in number, whilst the same number of cones succeeded the largest one posteriorly. The specimen now described possessed a still larger number, and six denticles extended anteriorly; but the general character of the tooth appears to render its relationship beyond doubt; and although so widely separated from each other geographically, they are not widely separated in geological age.

No tooth has yet been identified belonging to the upper jaw, but it is not improbable that the dissociated cusps or denticles of the teeth may exist amongst the large number of teeth derived from the Faxe chalk.

Formation and Locality.—Etage Danien (Nyere Kridt): Faxe.

Ex coll.—Mineralogical Museum of the University of Copenhagen.
Family.—**SCYLLIIDÆ.**


First dorsal fin above or behind the pelvis; origin of the anal always in advance of that of the second dorsal; upper edge of the caudal fin not serrated. Teeth small, delicate, with a large middle cusp, and generally one or two smaller lateral cusps; arranged in numerous series.

*Scyllium planum,* Davis.

(Pl. xxxviii., fig. 9.)

Teeth having the characteristics of this genus have been found in the chalk-formation at Terkild-Skov in the Island of Seeland, and are comprised in the collection of the Zoological Museum of the University of Copenhagen, placed at my disposal by Prof. Dr. Lütken. They are small, and have probably been derived from the posterior portion of the lower jaw, though two or three teeth on each side the symphysis of the lower jaw are similar in form to the posterior ones, and these specimens may have been so situated. They have a breadth of 0.003 m. across the base of the crown. The principal median cone is only equal in height to half the breadth of the tooth; on each side is a lateral cone smaller than the median one. Each of the cones is rounded and somewhat thick at the base, tapering rapidly to a point with a slight curvature laterally. They are smooth. The base of the crown has a sygmoideal curvature. The root is short, and corresponds with the base in outline. Its outer surface slightly retreats from the base of the crown; the inner surface is expanded and bulbous.

The teeth from the chalk of Seeland are very similar to some of the teeth of the existing dogfish, *Scyllium canicula,* Cuv. Amongst fossil forms the nearest relationship will probably be found with *Scyllium (Thyllina) elongatum,* Davis: in this species, from the soft chalk of Sahel Alma in Mount Lebanon, the central cusp is much longer than in these specimens; and apart from the difference due to the position in the mouth, the teeth have generally a more graceful and

delicate outline. Two species have been described by A. E. Reuss* from the Planerarkalk of Bohemia and Saxony, under the names of Scyllium crassiconum and Scyllium humboldti; these were afterwards regarded by H. B. Geinitz,† and his determination was accepted by Anton Fritsch,‡ as distinct from the genus Scyllium, and they were transferred to the genus Scylliodus, Agass. The latter is considered by A. Smith Woodward§ as synonymous with Scyllium, who thinks the two species of teeth are doubtfully associated with the genus. A comparison of the teeth now described with the plates cited, whilst exhibiting a superficial resemblance of the coronal portion, confirms the doubt expressed by Smith Woodward; the roots of the teeth are of different form, and wanting in breadth and definition; instead of the concave under-surface of Scyllium they are deeply convex.

Formation and Locality.—Etage Danien: Terkild-Skov in Seeland.

Ex coll.—Zoological Museum of the University of Copenhagen.

Family.—**LAMNIDÆ.**


Body slender; snout much elongated. Second dorsal fin small, placed immediately above a long anal. Caudal fin much elongated, inferiorly notched near the extremity; pectoral and ventral fins large. Anterior teeth with a long slender principal cusp, and mostly with a pair of minute lateral cusps; postero-lateral teeth wider, central cusp shorter.

This genus was instituted, with the name Rhinognathus, and embraced a number of fishes, mostly in an imperfect condition obtained from the upper cretaceous beds of Mount Lebanon collected by the Rev. J. F. Lewis, now in the Edinburgh and British Museums. Unfortunately the name had been preoccupied by Fairmaire as a name for a beetle, and a second was rendered necessary. This has been provided by my friend Mr. A. Smith Woodward in the Catalogue of the Fossil Fishes in

---

*Verstein. böhm. Kreideform, pt. i., p. 4, pl. ii., figs. 21, 22; pl. xii., fig. 11. (Hybodus appendiculatus) and pl. iv., figs. 4–8.
‡ Rept. u. Fische böhm. Kreideform, p. 11, fig. 22, and p. 11, fig. 21. 1878.
the British Museum, and the genus has been found to embrace other species from various localities. From the Swedish chalk three species are added to the genus in the following pages.

*Scapanorhynchus tenuis*, Davis.

(Pl. xxxviii., figs. 10–13.)

Teeth small; crown attenuate, curved inwards and at its point slightly recurved; outer coronal surface and the apex smooth, inner surface minutely grooved on the basal portion; base, expanded laterally and supporting a minute sharply pointed denticle on each side; outer surface slightly convex; inner one rounded. Height of crown of anterior tooth 0·008 m.; width of the base equal to half the height. Latero-posterior teeth diminish in height to 0·004 m.; the width of the base is equal to the height; crown curved laterally, otherwise straighter than those in front. Root short; prominently bulbous on inner surface, outer one receding, inferior surface concave.

The teeth of this species, together with those of *S. latus*, next described, only exist in the Stockholm Collection from Oretorp. It is not without hesitation that it is proposed to separate them into two species. The step appears to be justified by the marked characteristics of the two, the graceful and slender attenuation of the crown in this species is very distinct from the broad, compressed crown of the next; the smaller dimensions of the base and the minute lateral denticles, whilst indicating close relationship, point to a specific difference.

*Scapanorhynchus tenuis* occurs in considerable abundance in the Faxe kalk at Faxe and Annetorp, and has also been found in the Saltholmskalk at Herfölge, Grenaa, Lügstör and Raunstrüpp. In the collection from the Zoological Museum of the University of Copenhagen are specimens from Faxe, collected by the late King Christian VIII. Teeth from the other localities named are comprised in the collections of the Mineralogical Museum of the University of Copenhagen.

**Formation and Locality.**—Etage Danien: Faxe; Herfölge; Grenaa, in Jutland; Logstor; Raunstrüpp; Annetorp, Scania. Etage Senonian: Calshamn; Oretorp.

**Ex coll.**—Riksmuseum, Stockholm; Mineralogical Museum and Zoological Museum of the University of Copenhagen, Geological Museum of the University of Lund.
Seapanorhynchus latus, Davis.

(Pl. xxxviii., figs. 14–17.)

Teeth broad in proportion to the height; outer coronal surface smooth, slightly convex, with a wide median sulcus at the base; the lower fourth of the height of the crown expands rapidly in breadth. Inner surface smooth and convex. A pair of lateral denticles attached to the broad base of the crown. Root thinner, antero-posteriorly, and the lateral bifurcations longer and deeper than in Seapanorhynchus tenuis from the same horizon. It also differs from the latter in the absence of grooves on the inner coronal surface; by its less rounded and attenuated form; and in the larger size and greater prominence of the lateral denticles.

This species is represented by examples from Annetorp in Sweden, in the Mineralogical Museum of the University of Copenhagen, kindly placed at my disposal by Prof. Johnstrup.

Formation and Locality—Etage Danien: Oretorp; Annetorp.

Ex coll.—Riksmuseum, Stockholm; Mineralogical Museum, Copenhagen.

Seapanorhynchus gracilis, Davis.

(Pl. xxxviii., figs. 18–20.)

Teeth, median cone elevated, compressed, acuminate, smooth, expanding widely at the base, and having on each side a well developed lateral denticle erect and acutely pointed. Anterior teeth curved sygmodially; the curvature of the posterior teeth is less decided, but they are inclined obliquely towards one or other side. Height of crown 0·012 m. in an anterior example; a latero-posterior tooth is 0·010 m., and the breadth of the base is equal to the height; the lateral denticles average one-fifth the height of the crown. Root short, prolonged laterally beyond the crown, inner surface prominent, outer one concave, inferior surface broad and concave. The teeth exhibit considerable variety in form, but are all characterized by the lateral denticles occupying a position allowing a perceptible interval between them and the median cone.

This species approaches Seapanorhynchus? subulatus, Ag.; it is distinguished by the lateral denticles standing erect from the base; those in S. subulatus are inclined at an oblique angle outwards. The teeth situated in the several parts of the jaws are generally similar in form to those figured of the type specimen.
of the genus *S. (Rhinognathus) lewisi*, Davis ("Trans. Roy. Dublin Soc.," N.S., vol. iii., p. 480, pl. xiv., fig. 4), from the cretaceous beds of Sahel Alma, Mount Lebanon, so far as the crown is concerned, but the roots of the anterior teeth of *S. lewisi* are deeply pronged; in this species they are short and widely distended.

*Formation and Locality.*—Danien: Faxe or Coraline Limestone, Annetorp. Lower Senonien: Oppmanna.

*Ex coll.*—Geological Museum, University of Lund.


Second dorsal fin and the anal of equal size, scarcely smaller than the first dorsal. No pit at the root of the caudal; side of the tail without keel. Teeth of all but the few hindermost series with a long, tapering, acuminate median cone with smooth cutting edges, base expanded with one or more pairs of lateral denticles, larger and sharper than those of Lamna; fourth tooth from the symphysis upon each side of the upper jaw very small; the teeth of the most anterior pair in the lower jaw small and relatively very slender.

Agassiz regarded Odontaspis as a sub-genus of Lamna; Müller and Henle considered that it was a distinct and well-defined genus, a view since accepted by Dr. Günther, and more recently by A. Smith Woodward, with considerable modification. The remains of this genus are found in the Cretaceous series of rocks, are abundant throughout the Tertiary formations, and still continue represented at the present time by a few surviving species.

**Odontaspis acuta, Davis.**

(Pl. xxxviii., figs. 21–24.)


Teeth lanceolate, slender, curved syngmoidally, sharply pointed, expanded base, with two pairs of lateral denticles acutely pointed and curved towards the central crown. In the anterior teeth the crown rises to a height of 0.020 m., with a width at the base of 0.005 m. The root between the bases of the second denticle on each side is double that of the base of the crown in width. The outer coronal surface is slightly convex, more or less depressed in the median...
portion at the base; the latter deeply concave. Inner coronal surface convex, smooth, projecting at the base; lateral margins fine, smooth. Root deeply bifurcated in the anterior teeth; the depth of the bifurcation diminishes in the teeth situated latero-posteriorly; forms a prominent bulb on the inside, with a corresponding depression externally. A median groove or sulcus extends vertically across the prominent part of the root. The posterior teeth have a much shorter crown, and the width of the root is greater; the latter in some of the teeth exceeding the former.

The teeth vary considerably in size, apparently according to age rather than a difference in the size of the mature fish. The smaller teeth are more slender, more acutely pointed, and have finer cutting edges than the larger ones, and have been subject to less attrition from use. The base, whilst possessing all the characters of the larger examples, has those characters less markedly developed, and, agreeing with the crown, of a more attenuated nature.

Whilst the teeth now described are in many respects similar to *O. hopei*, Ag., *O. dubia*, Ag., and *O. subulata*, Ag., they differ from all of them in possessing two pairs of lateral denticles, and in this character they approach *Odontaspis acuta*, Davis, from the Oligocene (Oamaru) formations of New Zealand. The example from the Danish locality of Annetorp, the highest horizon from which the teeth have been obtained (fig. 21), is remarkably similar to the example from Trellissic ("Trans. Roy. Dublin Soc.," n. s., vol. iv., pl. v., fig. 2), whilst those from Oppmanna more closely approximate to the specimen represented by fig. 1 (op. cit.).

In the Danish collections this species is represented by specimens, two of which are figured, from Faxe, Stevns, Annetorp, Luneberg, and Saltholm. The specimen from Stevns (Pl. xxxviii., fig. 23) is from the former collection of the late King Christian VIII. of Denmark.

**Formation and Localities.**—Etage Danien: Annetorp; Stevns; Faxe; Luneberg.

Senoniam II.: Oppmanna.

**Ex coll.**—Geological Museum, University of Lund; Riksmuseum, Stockholm; Mineralogical Museum, University of Copenhagen; Zoological Museum, University of Copenhagen.
Odontaspis acutissima, Agassiz.

(Pl. xxxviii., fig. 25.)


M. Agassiz designated under the above name teeth with a sharp point and long, cylindrical, sharp-pointed lateral cones. The origin of the tooth which forms the type of the species was unknown. A second example, associated with it provisionally, was derived from the molasse of Berthoud. The tooth represented (Plate xxxviii., fig. 25) possesses the characters ascribed by Agassiz to the species, and differs from others already noticed from the Swedish or Danish Cretaceous rocks. The height of the median crown is 0·008 m., and the breadth of the base is the same. The lateral cones are 0·003 m. in height, more than one-third the height of the crown. The root is short, retreating from the external base, concave below, and having the form of the base of the crown. The central cone is convex on both the inner and outer coronal surface; the lateral margins are sharp, and the apex pointed. The lateral denticles are well developed, very long and sharply pointed. A number of striae extend from the base towards the apex of each. The example is rather smaller than the one described by Agassiz, otherwise it appears to possess all its characteristics.

This species is distinguished from Odontaspis acuta, Davis, by its more graceful and slender form; the great size and prominence of the erect lateral denticles, of which there is only one on each side; as compared with the more or less curved denticles, generally two on each side, and comparatively small size in O. acuta, Davis.

Formation and Locality.—Etage Danien (Myere Kridt): Faxe.

Ex coll.—Mineralogical Museum, University of Copenhagen.
Odontaspis faxensis, Davis.

(Pl. xxxviii., fig. 26.)

Teeth small; the crowns of the anterior teeth on their external surfaces attaining a height of 0·01 m.; erect, acuminate. External coronal surface convex and smooth; internal one still more convex and also smooth; very slight ridge along each lateral margin. Base of crown expands laterally to a width of 0·012 m., and supports on each side a series of three denticles, decreasing in size as they recede from the principal cone; the denticles are short, conical, and sharply-pointed. The base of the crown is concave. The root is short, with a spongy structure, conforming in outline to that of the base of the crown.

This form is distinct from any other observed in the Cretaceous rocks of Sweden and Denmark. It, perhaps, most closely approaches Odontaspis acuta, Davis; but in that species there does not appear to be more than two lateral denticles, the second being much inferior in size to the first. In this species there are three lateral denticles on each side; all robust and distinct, and diminishing gradually in size from the centre.

Formation and Locality.—Etage Danien: Faxe.

Ex coll.—Mineralogical Museum, Copenhagen University.

Odontaspis kopingensis, Davis.

(Pl. xxxviii., figs. 27, 28.)

Teeth strong and robust; crown attains a height of 0·015 m.; on the median line, conical and pointed; external surface very slightly convex, smooth; internal surface deeply convex, rendering the crown very thick and strong. The base of the crown is curved upwards transversely, slightly on the external face, deeply on the internal; it is 0·015 m. across. A single pair of lateral denticles are present. They are triangular, and the apex of each is pointed. The root is large, deeply forked; the prongs well advanced on the external face; and the median part very prominent on the internal one.

The teeth comprised in this species appear to be rare; a single specimen occurs in the Riksmuseum at Stockholm from Saltholm, and another in the Geological Museum of the University of Lund from Kopinge. It most nearly approaches Odontaspis acuta, Davis, in general appearance; but the triangular and somewhat blunt character of the lateral denticles extending at right angles from the crown, are very different from the slender acuminate denticles, curving inwards towards the crown, of Odontaspis acuta. In this species there is no trace
of a second pair of denticles. In equally well preserved specimens of *O. acuta* there are generally two pairs.

It is significant, and confirms to some extent the isolation of this species, that at Kopinge and Saltholm the teeth of *O. acuta* have not been found; whilst in the localities in which that species occurs in abundance this remains undiscovered.

**Formation and Locality.**—Etage Danien: Saltholm. Etage Senonien (zone with *Belemnites mucronatus*): Kopinge, in the District of Ystad.

**Ex coll.**—Riksmuseum, Stockholm; Geological Museum, University of Lund.


Second dorsal fin and the anal very small. A pit at the root of the caudal fin, which has the lower lobe much developed; side of the tail with a keel. Teeth medium size, acutely triangular, compressed, slender, margins smooth, point acute, without lateral denticles. Posterior teeth, base broad as compared with the height, the teeth becoming smaller, shorter, and triangular.

Oxyrhina was regarded by Agassiz as nearly related to Lamna, being distinguished by its more compressed form, and the absence of lateral denticles. It occurs fossil in the Jurassic rocks, in the Cretaceous, and most abundantly in the Tertiary formations. The genus is represented by one existing species.

**Oxyrhina mantelli, Agassiz.**

(Pl. xxxix., figs. 1–7.)


Teeth "moderately robust; outer coronal face always nearly flat, often with large vertical wrinkles; inner coronal face gently rounded; root short, the branches very divergent, thick, expanded, and abbreviated. Anterior teeth large, triangular, and comparatively broad, the crown only gently curved outwards at
the apex; lateral teeth having the root much wider than the main portion of the crown, which thus exhibits a sudden basal expansion behind, and often, also, in front."—(A. S. W.).

The teeth of this species are smaller than those found in the English chalk, and whilst offering great diversity in form, as exhibited in the specimens represented (Plate xxxix., figs. 1–7), the small teeth, very short and extremely broad, which Smith Woodward* represents as occupying the posterior portion of the jaws, are not represented. The root is deeper but less divergent laterally than those hitherto described; the external surface is deeply concave; the internal surface exhibits a correspondingly prominent convexity. The oblique teeth from the posterior portion of the jaw do not possess so great an expansion of the internal surface of the root as those in front; the root is flatter, as well as more greatly expanded laterally.

In the Danish collections this species is represented by examples from the chalk of Saltholm and Annetorp; all in the Mineralogical Museum.

*Oxyrhina mantelli* has a very wide range both in time and the area over which its remains have been discovered. It is a common fossil in the chalk of the south of England, and is found in the Cretaceous rocks of Sarthe, in the north of France, in Belgium, Germany, Bohemia, Galicia, Russia, Sweden, and Denmark; and in America it has been found in the Cretaceous beds of Kansas, the Mississippi, and Alabama, and a closely related species, *Oxyrhina haasti*, Davis, has been discovered in New Zealand.

Formation and Locality.—Etage Danien: Saltholm; Annetorp and Limhamn Skåne. Etage Senonien (zone with *Actinomax mamillatus*): Oppmanna; most abundantly at the latter.

Ex coll.—Geological Museum, University of Lund; Riksmuseum, Stockholm; Mineralogical Museum of the University of Copenhagen.

*Oxyrhina lundgreni*, Davis.

(Plate xxxix., figs. 8–13.)

The teeth comprised in this species exhibit considerable variation in form and size. The anterior teeth are long, erect, with a slightly recurved apex; those which have occupied an intermediate position on the sides of the jaws are shorter, with a broader base and greater curvature; whilst the posterior teeth are little more than half the length of those occupying an anterior position, and

* Cat. of Foss. Fishes in the British Museum, part. i., pl. xvii., figs. 9–21.
have a decidedly sygmoidal curvature combined with a peculiar twist outwards towards the apex.

The length of the anterior teeth is 0·05 m., the lateral diameter, midway between the base and the apex, is 0·012 m.; the lateral margins are produced so as to form a fine cutting surface, and gradually converge to an acuminate apex; towards the base the tooth thickens, and rapidly expands to a diameter of 0·025 m. The enamelled surface is invariably smooth near the point; in some examples the internal surface maintains this character quite to the base, whilst the external is only slightly grooved; in others deep channels extend from the base far towards the apex on both the internal and external surfaces, usually more pronounced on the latter. The channels are divided into more numerous, but smaller, grooves at the base. The external surface of the anterior teeth is less rounded than the internal one; in those teeth situated posteriorly the curvature of the two surfaces is about equally well developed. The root is not well preserved in any of the Swedish examples, but sufficient remains on some of the specimens to show that it was much wider than the crown, and that the internal surface was produced so as to form a prominent median bulb. The posterior teeth are less deeply grooved, and more rapidly and uniformly converge to a point than the anterior ones: an average length is 0·03 m., with a lateral diameter of 0·017 m. at the junction of the enamelled surface with the root.

A beautifully preserved specimen, showing the crown and root of a tooth, which occupied a lateral position in the jaw, occurs in the Mineralogical Museum at Copenhagen. It is embedded in a matrix of the coraline limestone or chalk of Faxe. To some extent this is unfortunate, because the internal surface of the root is hidden by the matrix; but it is very probable that the fact of its being attached to the matrix has preserved the crown and root intact. The examination of many hundreds of specimens has shown that the attachment of the crown to the root is more or less fragile, and the root being apparently less easily detached from the matrix than from the crown the two parts are rarely found associated. It may be imagined, however, that a more careful search in the limestone forming the matrix at the base of the crown would result in the discovery of many other examples of the root. The height of the crown in this specimen is 0·035 m., and its width across the exposed external surface is 0·012 m. The crown is curved slightly backwards, and at the same time exhibits a sygmoidal curvature of the inner and outer surfaces. The outer surface is deeply grooved from the base upwards; the inner one smooth; the margins have a sharp cutting edge, and the apex is acuminate. The root extends at an obtuse angle from each margin of the crown, forming a pair of processes expanding to a diameter of 0·032 m., nearly equal to the height of the crown. The under surface of the root is only slightly concave. The total height of the
tooth, from the anterior extremity of the base of the root to the tip of the crown, is 0.05 mm. The root has apparently an open and porous structure.

These teeth present a considerable divergence from the usual characteristics of the genus Oxyrhina in the long erect crown, and more especially in the wide separation of the lateral extensions and the peculiar flat under-surface of the root. It may at some time be found desirable to make it the type of a new genus; and it is not without hesitation that I have placed it as a distinct species in the genus Oxyrhina.

This species approaches in form to that of Oxyrhina grandis, Davis, from the Cretaceo-Tertiary beds of New Zealand. It may be distinguished by its greater length as compared with the width, its more erect and less triangular form, and the presence of deep grooves extending vertically on the external, and, in most cases, on the internal, surface.

The teeth are abundant in the Faxekalk; and numerous specimens from Faxe are in both the Mineralogical and Zoological Museums of the University of Copenhagen. Specimens from Saltholm also occur in each collection, and others from Annetorp are in the former.

Formation and Localities.—Étage Danien and Étage Sénonien, in zones 1 and 2: Limhamn, in the District of Malmá; Annetorp; Faxe; Köpinge, in the District of Ystad; Saltholm; and Oppmanna, in the District of Kristianstad.

Ex coll.—Riksmuseum, Stockholm; Geological Museum, University of Lund; Mineralogical and Zoological Museums of the University of Copenhagen.

Oxyrhina zippei, Agassiz.

(Pl. xl., figs. 1–7.).


Teeth acuminate, slender, compressed; enamel smooth; with or without
slight vertical grooves from the base upwards on the outer coronal surface, giving it the appearance of a median depression; laterally the crown exhibits a sigmoidal curvature; height 0·018 m.; breadth at base of crown 0·009 m.; outer coronal surface slightly convex below, flat above; inner surface equally convex with the outer; margins thin and sharp. Base of crown concave and receding on the outer; prominent and overlapping the root on the inner surface; laterally wide and expanded; no lateral denticles. Root short, compressed antero-posteriorly like crown; laterally extending beyond crown, with bluntly-terminating divergent branches; base with comparatively slight concavity. Postero-lateral teeth broader, shorter, and more acutely pointed.

These teeth are separated from *Odontaspis elegans*, Ag., by the total absence of lateral denticles, and, though superficially resembling them in form, they are thinner and more compressed. The posterior teeth are broader and shorter, as compared with the anterior ones, than in *O. elegans*. The broadest teeth approach *Oxyrhina enyssii*, Davis, a species found in the Senonian formations of Oamaru and Waipara in New Zealand. ("Trans. Roy. Dublin Society," N.S., vol. iv., p. 28, pl. v., figs. 17–20.)

They appear to be most closely associated with, and to possess the characteristics ascribed by Agassiz to a number of small teeth from the Greensand of Ratisbon ("Poiss. Foss.," vol. iii., p. 284, pl. xxxvi., figs. 49–52). Agassiz was in doubt as to the presence of lateral denticles, because the roots and a portion of the base in the examples at his disposal were broken off. With the specimens from the Swedish Cretaceous rocks this point is made clear; the base and roots are well preserved, and there are no lateral denticles. Fig. 48 (*op. cit.*), which Agassiz included in this species, H. E. Sauvage considers to be the lateral denticle of a large tooth of *Otodus* from the white Chalk of Villavard, which is described as *O. spathula* ("Rech. sur les Poiss. Foss. du terrain Crétacé de la Sarthe," *Bibl. Ecole des Hautes Etudes,* vol. v., pp. 23 and 33). The type of *O. zippel*, represented in the figures 49–52, and with fig. 48 eliminated, agrees with the examples from Oppmanna, and the latter appear to be naturally included in the species.

Oxyrhina conica, Davis, sp. nov.

(Pl. xl., figs. 8–10.)

Teeth small; anterior teeth long, tapering to a sharp point, with a more or less sigmoidal curvature; posterior teeth broader at the base, shorter, and with a scarcely perceptible curvature. Height of anterior tooth 0·008 m.; breadth of base 0·003 m.; outer coronal surface flat on the lower, slightly convex on the upper, part, with minute ridges at the base, which disappear higher, leaving an even and smooth surface; inner coronal surface convex, with similar ridges near the base to those on the outer face; margin of base curved upwards in centre. Root extended beyond the base of the crown laterally, and on the inner surface; postero-inferior surface flattened, or slightly concave. No evidence of lateral denticles. The root in several examples is well-preserved; in the majority, however, it is broken away, and only the outer shell of the tooth is preserved.

Two specimens somewhat larger, but possessing the characters of this series, have been found at Köpinge.

The entire absence of lateral denticles on the teeth which are sufficiently well preserved to afford evidence leads to the inference that the whole of the teeth have probably been devoid of them. They are similar in form to a number of teeth found in the Pondicherry Beds of India, and described by Sir Philip Egerton in the "Quarterly Journal of the Geological Society," vol. i., p. 171. They were imperfectly preserved, and were referred to the genus Odontaspis, with the specific appellation, O. constrictus. Although it is devoid of lateral denticles, Egerton considers that more perfect specimens might possess them; and he indicated a probable relationship to Lamna (Odontaspis) subulata, Agassiz, from the Lower Greensand of Neufchâtel ("Poiss. Foss.," vol. iii., p. 296, pl. xxxvii. a, fig. 5). The latter has well-developed lateral denticles, and a deeply-forked root. The Pondicherry teeth have a similarly flat inferior surface to one of the specimens now described, so far as can be ascertained from the imperfect specimens. Later, A. Smith Woodward has transferred Odontaspis subulata, Ag., to the genus Scapanorhynchus ("Catalogue of the Fossil Fishes in the British Museum," pt. 1., p. 356), and has included O. constrictus, Eg., as a synonym of the same species.

The Oretorp specimens are clearly distinct from O. subulata, Ag., and the absence of lateral cusps removes them from the genus Scapanorhynchus, and indicates their relationship with Oxyrhina; it is therefore proposed to place them in that genus.

Formation and Locality.—Senonian: Oretorp, Köpinge (?).

Ex coll.—Riksmuseum, Stockholm.
Vertebrae of Oxyrhina mantelli, Ag.

(Pl. xxxix., fig. 14.)

Examples of vertebrae of Oxyrhina occur at Köpinge, in the Étage Sénonien, characterized by the presence of Belemnella mucronata. The vertebrae have a diameter of about 0·06 m., and are 0·015 m. in thickness. The anterior and posterior surfaces are deeply biconcave, with the centre pierced. The concave surfaces of the vertebra are marked by a series of concentric rings, giving a more or less corrugated appearance, represented in the figure.

Formation and Locality.—Upper Senonian: Köpinge.

Ex coll.—Geological Museum of the University of Lund, Sweden.


Teeth of medium size, elongated, narrow in proportion to the height, sharply pointed, with cutting edge smooth, base expanded, lateral denticles present, usually one pair; root large and deeply bifurcated.

The teeth of Lamna may be distinguished from those of Otodus by being rounder and less compressed, and having the lateral cones smaller and pointed.

Oxyrhina is devoid of lateral denticles, and is thinner and more triangular in outline than Lamna. This latter genus first appears in the Chalk formation, and is still existing.

Lamna elegans, Agass.

(Pl. xl., figs. 11—17.)


Lamna elegans, . . . . Agassiz, L., 1843. "Poiss. Foss.," vol. iii., p. 289, pl. xxxv., figs. 1—5. (non figs. 6, 7); pl. xxxvii., a, fig. 50 (non fig. 58).

A large number of teeth have been found in the Senonian rocks at Oppmanna, and in other localities less abundantly, which present the characteristic appearance of Lamna elegans, Agass., and associated with them are teeth, shorter, broader at the base, and having the fangs of the root more widely separated, which have probably been located in the posterior parts of the jaws of the same species. Anterior teeth elongated and narrow, varying in size, the longest attaining a height of 0.035 m. from the base of the enamelled crown to the point; the width at the base is 0.007 m. The outer coronal surface is distinctly convex on the lower half, flatter above; smooth, except a few faint striations at the base; inner face deeply convex and smooth; lateral margins produced, very thin, and sharp. The crown is slightly curved, in some specimens scarcely perceptible. The root is
rarely preserved perfect; deeply bifurcated; outer surface concave, retreating directly from the base of the crown; inner surface bulbous and prominent; lateral branches separated at a right angle. A minute lateral denticle is occasionally preserved, tipped with enamel, and slightly separated from the principal cone. The posterior teeth are broader, shorter, and more compressed than the anterior ones. A tooth apparently proportionate in size to those described above is 0·025 m. in height and 0·010 m. in width; its outer surface is flatter, and the inner less convex, whilst its curvature is more pronounced than is that of the anterior teeth; the branches of the root are smaller and more widely separated, and the inner surface is less bulbous.

This species is most abundantly represented in the Swedish collections from the Senonian formation at Oppmanna; whilst to the Danish collections the Faxe and Annetorp beds, in the Danian series, have contributed most largely. It may be noted that the specimens from Faxe are very abundant, but they are generally smaller than those from Annetorp.

Formation and Localities.—Étage Danien: Faxe Limestone: Saltholm; Annetorp; Limhamn; Malmå district. Étage Sénonien Inférieur: Kjuge, Scania; Ifo; Oppmanna; District of Kristianstad; Sissebück.

Ex coll.—Geological Museum, Lund University; Riksmuseum, Stockholm.

**Lamna incurva**, Davis.

(Pl. xl., figs. 18–24.)


Teeth robust; crown smooth, with marked sigmoidal curvature; height of anterior teeth 0·020 m.; breadth at the base 0·005 m., from which the tooth tapers to a point; outer coronal surface convex; inner surface deeply convex; the lateral margins form a cutting edge near the apex; nearer the base the sides of the teeth are rounded. A comparatively small number of specimens possess a single pair of lateral denticles, minute and sharp-pointed. The crown of the posterior teeth is shorter than that of the anterior ones; it is broader, more rapidly acuminate and compressed. The root is prominently bulbous on the inner surface; a deep vertical notch extends along it; lower, the root is divided into two fangs, at no great distance apart in the front teeth, but much more widely separated in those situated behind.
This species, instituted for the reception of teeth from the Cretaceo-Tertiary strata of New Zealand, is now found to occur in the Cretaceous system of Sweden. The teeth from the latter locality are, however, smaller than the type specimens from New Zealand. In addition to the examples sent from the museums in New Zealand, several specimens are recorded by Mr. A. Smith Woodward which are in the collections at the British (Natural History) Museum, all from localities in New Zealand.

A small number of teeth have been obtained from the Faxe limestone at Annetorp, and are included in the Lund collections. From Oppmanna the number of examples is much larger; and it is from this locality that the types have been selected which are represented on Plate xl. There is no appreciable difference, however, in the teeth from the two formations.

Numerous specimens are comprised in the Danish Collections, principally derived from the Saltholmkalk.

**Formation and Localities.—**Étage Danien: Faxe Limestone: Annetorp; Saltholm; Luneberg; Limhamn, Skåne; Faxe. Étage Sénonien II.: Oppmanna; Sissebäck. Étage Sénonien I.: Kjuge.

**Ex coll.**—Geological Museum, Lund University; Riksmuseum, Stockholm (Sissebäck); and Limhamn Mineralogical and Geological Museums of the University of Copenhagen.


This genus is defined by Agassiz as occupying an intermediate position between Carcharodon and Lamna or Oxyrhina. It may be distinguished from Oxyrhina by the presence of a well-defined lateral denticle on each side the median cone, more frequently rounded than compressed or pointed. The median cone is broad and compressed; similar in form to that of Oxyrhina. In Lamna and Odontaspis the lateral denticles are smaller, more cylindrical and pointed, and the teeth generally more elongated. The absence of marginal serrations serve to distinguish this genus from Carcharodon. The root is largely developed and thick, but is devoid of the deep lateral projection which distinguishes Lamna.

This genus is found abundantly in the Cretaceous and Tertiary formations, but, so far as known, has since ceased to exist.
Otodus appendiculatus, Agassiz.

(Pl. xli., figs. 1–11.)


Teeth medium size; median cone of anterior teeth high, robust, in form of isosceles triangle; point slightly recurved outwards; height of large example 0.030 m.; breadth at base of cone 0.017 m.; outer coronal surface slightly convex or flat; median basal portion depressed, with or without grooves; inner coronal surface convex, smooth; lateral margins constitute a sharp cutting edge. Single pair of divergent lateral denticles broad, compressed, pointed; breadth of base, including lateral denticles, 0.030 m. Postero-lateral teeth as broad as long; median cone more or less triangular; lateral denticles larger comparatively than those of the front teeth. Root larger, with deep lateral prongs; external surface depressed and hollow; internal one prominently convex.

In the collection sent from the Zoological Museum at Copenhagen there are a large number of teeth from the Chalk of Faxe which undoubtedly belong to this species. Associated with them are still larger numbers without lateral denticles,
and for the most part without root. The latter do not present any character which will distinguish them from the median cusp of Otodus appendiculatus, Ag., but are so similar in size and form that there can be no other course but to include them, although without lateral denticles, in the same species. Had they been found dissociated from the undoubted teeth of Otodus they would have been considered as teeth of Ozyrhina mantelli, Ag.; and it may still be possible that more minute investigation in the strata at Faxe will prove that the latter is their proper location. The peculiar nature of the matrix, and the manner in which it is cemented together, renders the extraction of the fish-teeth in a perfect condition difficult; and the lateral portions, as well as the base of the tooth, are very likely to be broken away unless especial care is exercised.* Specimens to which the matrix is still attached, in nearly every instance exhibit one or both the lateral denticles in situ; but it is easy to conceive that if the tooth were extracted from the limestone the median large crown would be broken off without the lateral cones and base. If the teeth have been collected by operatives unskilled in this branch of palæontology, they would probably not exercise the care necessary to obtain the specimens perfect, and this may account for their present condition.

The teeth from Oretorp are smaller in size than those from the remaining localities, and in a very large proportion of them the root is broken off, the median cone alone remaining. A few, however, are more perfect, and the root and lateral denticles are preserved.

Sauvage ("Bibl. des Hautes Études," vol. v., p. 27) doubts whether all the teeth figured by Agassiz ("Poiss. Foss.," vol. iii., pl. xxxii., figs. 1–25) should be included in the same species, and considers that several species are confounded together. Agassiz himself appears to have held the same opinion, and states that among the number of teeth figured there are several which differ from each other more than certain species which have been described as distinct. The teeth represented by figs. 19–25 were probably a distinct species; and doubt was expressed as to whether figs. 17 and 18 were not also different. If fig. 7 be eliminated along with fig. 9, the latter being possessed of two pairs of lateral denticles, and the former being more of the form of Odontaspis than that of Otodus, the remaining figures seem to possess closely related characters; and, when so curtailed, the larger number of specimens from the Swedish Cretaceous system falls naturally into association with this species. Mr. A. Smith Woodward records the occurrence of a tooth resembling the original of fig. 7 (Agassiz, tom. cit.) associated with a group of about twenty-five others in a block of chalk from

* The three specimens on the tablet in the collection of the Zoological Museum, No. 305, may be referred to as exhibiting the character here indicated.
the neighbourhood of Maidstone. In the same group is a small tooth which may possibly be regarded as the third tooth of the upper jaw, closely resembling a tooth assigned to Lamna subulata by H. G. Geinitz ("Palæontogr.", vol. xx., pt. ii., pl. xxxviii., fig. 31).

In the Swedish collections the most numerous specimens are obtained from Oppmanna, in the lower stage of the Senonian beds, characterized by the presence of Actinocamax mammillatus, and are now located in the Museum of the University of Lund. In the Danish collections the best locality is Faxe, the Chalk of that district yielding large numbers of teeth in a very beautiful state of preservation. Several of these have been selected for illustration. The University Zoological Museum possesses a series from the Saltholmkalk, which formed part of the original museum collected by King Christian VIII.

Associated with the teeth are vertebrae which in all probability belonged to the same genus.

Swedish.

Formation and Locality.—Étage Danien: Annetorp. Étage Sénonien II.: Oppmanna. Faxe Coralline Limestone; Oretorp; Balsberg. Sénonien I.: Kopinge; Kjuge.

Ex coll.—Geological Museum, University of Lund, from all the localities except Oretorp and Kopinge. The teeth from Oretorp and Kopinge are from the Riksmuseum, Stockholm.

Danish.

Formation and Locality.—Étage Danien: Skillingsbro'; Saltholm; Stevns; Herfölge; Hjern; Annetorp; Faxe; Terkild-Skov in Seland; Ignaberga, Scania.

Ex coll.—Mineralogical Museum and Zoological Museum of the University of Copenhagen.

Underla linehamnensis, Davis, sp. nov.

(Pl. xli., figs. 12.)

The teeth which are included in this species are distinguished by the great strength and thickness of the crown, and by the large and prominent development of the root. The crown is 0.030 m. in height; the width of the base is 0.020 m.; a lateral extension of the root beyond the width of the crown increases
its width to 0.030 m., and enables it to support on each side a lateral denticle. The outer coronal surface is convex in the median and upper parts; the lower part is depressed and flat; a slight median ridge extends from the base one-third of the height; enamel smooth. The inner coronal surface is deeply convex, expanding outwards at the base, without folds or striations. Lateral margins trenchant, continuous with the lateral denticles; the base of the enamel rises in a gentle curve from each side to the centre on both the inner and outer surface. The lateral denticles are strong, convex on each surface, rather more so on the inner than the outer one; margin with a sharp edge; point inclined away from the crown. Root large and massive, laterally extending beyond the enamelled surface. The outer surface is depressed from the base of the crown; from the inner coronal surface the root projects very boldly, extending forward nearly horizontally, the diameter being 0.016 m. The inferior surface of the root is deeply concave in the middle, with lateral projections extending downwards at an acute angle.

The specimens referred to this species are from Limhamn, in the district of Malmå, in the Danien formation. They approach, on the one hand, _Otodus appendiculatus_, Agassiz, and on the other, _Otodus spathula_, Sauvage ("Bibl. Ecole Hautes Études," vol. v., No. 9, p. 32, pl. i., figs. 27–32). The latter is from the white chalk occurring at Villavard, in the Sarthe. The crown is similar in form to the species now described. The characteristic of the Sarthe species consists in the lateral cones being separated from the principal one; the enamel of the latter does not extend to the former. This feature separates it clearly from the Limhamn type, in which the lateral cones are connected by the continuity of the enamel with that of the crown; the downward projections of the root are also much deeper than in the examples described by Sauvage; and the root is altogether much thicker. The latter character serves also to distinguish the species from _O. appendiculatus_, Ag. The crown of the tooth is stronger and thicker, and more convex on both the inner and outer surfaces.

_Formation and Locality._—Étage Danien: Linhamn, Skåne.

_Ex coll._—Riksmuseum, Stockholm.
Otodus obliquus, Agassiz.

(Pl. xli., fig. 13.)


Otodus obliquus, . . DIXON, F., 1850. "Foss. Sussex," p. 204, pl. x., figs. 32-35; pl. xv., fig. 11.


The tooth represented by the figure indicated above is the only one occurring in the collections examined. It is from the Zoological Museum of the University of Copenhagen, and was obtained from the Cretaceous formation at Rugaard, near Grenaa, in Jutland. The tooth is strong and robust; the crown is 0.03 m. in height; the width of the base of the crown is 0.033 m., of which one-third is occupied by the lateral denticles. The outer coronal surface is moderately convex and smooth; the inner face is well-rounded and also smooth. The lateral margins and apex thin out to a fine cutting edge. Lateral denticles, one on each side, are broad, smooth, and acuminate. The root is very thick; and on the inside the median portion forms a prominent and expanded boss; the outside retreats
from the base of the crown; the under surface is deeply concave, the lateral prongs extending and forming deep projections.

This tooth is indistinguishable from the teeth of *Otodus obliquus*, Ag., of the Red Crag of the Eastern Counties of England; and although not previously recorded from measures lower than the Tertiaries, there appears no alternative but to place it with this species. Its nearest relation amongst the Scandinavian fishes is with *Otodus appendiculatus*, Agass.; but from that species it is distinguished by the thickness and rounded form of the crown, and by the great inner extension of the root.


*Ex coll.*—Zoological Museum, University of Copenhagen.

**Vertebrae of Otodus.**

(Pl. xl., figs. 25, 26, 27; pl. xlii., figs. 1, 2, 21.)

Vertebrae of this genus occur with considerable frequency; they vary in size, and probably belonged to more than one species. The larger examples measure 0.055 m. in diameter, and the smaller ones 0.015 m. The internal structure possesses the characteristics represented by Professor Carl Hasse* in the Plagiostomi asterospondyli, the calcifications between the anterior and posterior concave surfaces assuming a radiating or star-like arrangement in vertical section. The vertebrae of Otodus are classed with Ginglymostoma and Crossorhinus in the Scyllioliamnidae.

*Formation and Locality.*—Étage Danien: Faxe. Étage Sénonien: Köpinge, Ignaberga.

*Ex coll.*—Zoological Museum, University of Copenhagen; Geological Museum, University of Lund.

**Series of Small Vertebrae.**

(Pl. xl., figs. 28–32.)

A number of vertebrae occur in the collection from the Riksmuseum at Stockholm which have been found in the Chalk beds at Köpinge. They are in some instances beautifully preserved, and probably belong to some of the smaller genera of Lamnidae.

*Formation and Locality.*—Étage Sénonien (zone with *Belemnites mucronatus*): Köpinge, in the district of Ystad.

*Ex coll.*—Riksmuseum, Stockholm.

Coprolite (?) Otodus.

(Pl. xxl., fig. 33.)

The coprolite figured is from the Museum at Stockholm, and is the only example occurring in any of the collections. It closely resembles the coprolite of Macropoma, and similar objects found in the Cretaceous formation of Bohemia were identified by Reuss* as the coprolites of Macropoma mantelli, Ag. Fritsch† expresses his conviction that, so far as the specimens represented on pl. v., figs. 1–5, by Reuss, were concerned, they were the coprolites of a Selachian, and probably belonging to Otodus appendiculatus, Ag. Some of the coprolites exhibited peculiarities of form which could not be attributed to Macropoma; and, further, there was no evidence of the presence of Macropoma in the beds from which the coprolites were obtained. The Swedish and Danish Chalk offers a parallel case. Taken independently, it is probable that the coprolite now figured might be associated with Macropoma; but no evidence of the scales or bony skeleton of this genus has been found, and the absence of such evidence leads to the inference that the coprolite may, with a reasonable amount of probability, be referred to Otodus appendiculatus, the remains of which are abundant.

Formation and Locality.—Étage Sémonien: Faxe.

Ex coll.—Riksmuseum, Stockholm.


Second dorsal fin and the anal very small. A pit at the root of the caudal fin, which has the lower lobe well developed; side of the tail with a keel. Teeth large, erect, compressed, triangular, without basal cavity, margin serrated.

* "Verstein. der Böhmischen Kreideformation," p. 11, pl. v., figs. 1–8; pl. iv., figs. 68–80. 1845.
† "Reptil. u. Fische der Böhmischen Kreideformation," p. 18. 1878.
Carcharodon rondeletii, Müller and Henle.

(Pl. xlii., fig. 14.)


Carcharodon tornabene, Gemmellaro, G. G., 1857. Tom. cit., p. 309, pl. i.a, fig. 12.


A portion of a tooth, probably belonging to this species, has been found in the Chalk at Faxe, and is now in the collection of the Mineralogical Museum at the University of Copenhagen. A part of the specimen has been cut away, apparently for the purpose of making microscopical sections; the remaining part exhibits the left half of the crown and root. The crown is 0·03 m. in height; the length of the margin of the tooth, including the root, is 0·045 m. The crown is thin and compressed; the outer surface is slightly convex, almost flat, with the apex slightly curved outwards. The inner surface is convex. The crown is widely expanded, its breadth equaling its height. The margin is serrated; there is no evidence of lateral denticles. The root, like the crown, is compressed; spongy in structure. The inferior surface concave, and conforming in outline to the base of the crown.

This specimen agrees in all essential particulars with the specimens described by L. Agassiz as Carcharodon sulcidens, Ag., from the Tertiary strata of Italy.
These specimens, and others, have since been studied by R. Lawley, and the results of his investigations have shown that the species is the same as *C. rondeletii*, M. & H., which still exists in the tropical seas. Smith Woodward has accepted the views held by Lawley, and regards the Italian fossil fish remains as pertaining to the existing species. Should all these determinations prove correct, the occurrence of a representative of the existing species in the Chalk of Faxe will be interesting.

*Formation and Locality.—* Étage Danien (Nyera Kridt): Faxe.
*Ex coll.—* Mineralogical Museum, University of Copenhagen.


Known only by the teeth, and confined to the Cretaceous rocks. Small or medium size; compressed, and more or less triangular; mature specimens generally with uniform marginal serrations; in young examples the serrated edge is sometimes wanting. Root large, slightly hollow beneath.

They resemble to some extent the teeth of Galeus and Galeocerdo; but Agassiz has pointed out that they are readily distinguished by the microscopical structure of the teeth ("Poiss. Foss.," vol. iii., p. 224), which in this genus are solid, as in the Lamnidae; whilst the teeth of Galeocerdo and Galeus agree with the remaining Carchariidae in being hollow in the interior. Corax is readily distinguished from Galeus by the smooth anterior margin of the teeth of the latter; and those of Galeocerdo are very strongly crenulated on the basal extremity, whilst the serrations of the crown are comparatively feeble. The solidity of the structure of the teeth of Corax recalled to Agassiz the similarity to Notidanus, and M. Sauvage ("Bibliothe. de l’École des Hautes Études," vol. v., No. ix., p. 39), after considering the superficial and microscopical relationship of Corax with Galeus and Notidanus was disposed to consider that structure was of greater importance than external form, and that, in a truly natural classification, Corax will be found to have a greater affinity with Notidanus. Corax, so far as is known, became extinct with the Cretaceous period, and it remains to be seen whether its descendants must be looked for amongst the Tertiary and existing Galeus and Galeocerdo or in the Notidanidae.
Corax lindstromi, Davis, sp. nov.

(Pl. xlii., figs. 3–11.)

Teeth of medium size, varying much in height and breadth of crown, but all possessed of an arched anterior margin, extending far down, and enveloping the base or root, and a more or less deep indent of the posterior margin. A large example has a breadth across the base of the crown of 0·022 m.; the height of the crown on the external surface is 0·012 m., and on the internal one 0·009 m. The size varies to specimens having only one-third these measurements. The external surface of the crown is slightly convex in the median part, flat towards the margins; slight folds in the enamel rise from the base, and disappear higher on the crown. Internal surface convex, with delicate, broad folds near the base. Line dividing the crown from the base deeply arched upwards on internal surface, less so on the external one. Anterior margin boldly arched, and extending over the root. Posterior margin straight, or with a slightly sigmoidal curvature, on upper part; the lower part extends thence more or less horizontally, forming a deep indent, at an angle varying from a right-angle to one which is obtuse. The margins are uniformly and finely serrated over their whole length; the apex of the crown is acuminate, the root is large, equal in breadth to the crown, flat on the external surface, convex on the internal one, inferior surface slightly concave.

The study of the large series of specimens of the genus Corax in the British Museum has induced Mr. A. Smith Woodward to reduce the number of species to three, viz. Corax pristodontus, Ag., C. falcatus, Ag., and C. affinis, Ag. The last is a small species, the principal teeth of which have a much elevated, slender crown, with a notch on both the posterior and anterior margin, producing a broad posterior, and a narrow anterior denticle. Corax falcatus is medium sized; the crown is elevated, not so much so as in C. affinis; the anterior coronal margin is arched, but not so much as in the Corax pristodontus; the posterior coronal margin is more or less deeply notched, and the base of the enamel on the external surface is comparatively straight. Corax pristodontus has a very broad base, a large tooth, has little or no indentation on the posterior margin, and the anterior margin of the crown is prolonged for a considerable distance over the root; the base of the crown on the external surface being thus rendered much arched, a feature not very well exhibited in the specimens figured by Agassiz ("Poiss. Foss.,” vol. iii., pl. xxvi., figs. 10–13). The teeth now described from the Lower Senonian strata of Ifö and Oretorp appear to occupy an intermediate position.
between *Corax pristodontus* and *Corax falcatus*. They have a well-marked indentation, or notch, on the posterior margin, and at the same time exhibit a long, arched extension of the anterior margin over the root, and the base of the crown on the external surface is rounded. They may either be considered as a connecting link uniting the two species, or as an independent species.

M. Reuss ("Verst. der Böhmischen Kreideform," 1845, pt. 1, p. 3) has expressed the opinion that only one species of *Corax* existed during the Cretaceous era, to which he gave the name *C. heterodon*, including in it *C. kaupii*, *C. falcatus*, *C. appendiculatus*, and *C. affinis*, of Agassiz. M. Herbert ("Mémoires de la Soc. Géol. de France," 1854, ser. ii., vol. v., p. 353) arrived at a similar conclusion after a very careful study of a large number of specimens from the Chalk of Meudon and Cotentin, embracing all the variations between *Corax kaupii* and *C. pristodontus*, and he suggested the name *Corax pristodontus*, Ag., as being the earliest, under which all the others should be affiliated; whilst M. Pictet was led to remark (Pictet et Campiche, "Foss. Crétacé de Sainte Croix," 1858, ser. ii., p. 80) that there was very small probability that so many and varied forms could be associated on the jaws of the same fish; and M. Sauvage says that it is not to be supposed that only a single species had lived in the Cretaceous seas from the epoch of the Gault to that of the Maastricht beds ("Bibliothe de l’École des Hautes Études," 1872, vol. v., art. 9, p. 40).

In the midst of so many learned opinions, a clear and definite judgment on this difficult and intricate set of phenomena is impossible. There may be some hope that a complete dental series may be found which will exhibit the natural arrangement; but until this happens all classification must of necessity be provisional. Whilst recognizing the possibility that many of the specimens now supposed to represent separate species may ultimately be proved to have been associated in the same jaws, it may be advantageous to consider them as distinct until material shall be acquired which will render their determination certain.

*Formation and Locality.*—Étage Sénonien Superieur: Köpinge; Étage Sénonien Inferieur (zone with *Actinocanax mammillatus*, Nils.): Ifö; Oretorp; Ignaberga; Oppmanna; Balsberg.

*Ex coll.*—Riksmuseum, Stockholm; Geological Museum of the University of Lund.
Order.—HOLOCEPHALI.

Family.—EDAPHODONTIDÆ, OWEN.

Genus. Ischyodus, Egerton.

_Ischyodus brevirostris_, Newton (Ag. MS.).

(Pl. xlili., figs. 12–15.)

Chimaera (Ischyodon) brevirostris, Agassiz, L., 1843. "Poiss. Foss.," vol. iii., p. 344 (name only).


Several specimens of this Chimaeroid occur in collections from the Lund University. Mostly they are in a fragmentary condition. The specimen (fig. 12) is an example of the left mandible, and the most perfect in the collection. The posterior part of the jaw is defective and broken; this is the case with all the specimens, and has been explained by Newton. As the anterior parts of the jaws are worn away, they are constantly pushed forward by the growth of new matter behind, and the posterior parts always growing, and consequently being imperfectly ossified, they are readily broken and damaged. The anterior margin and the sinuous indentations which characterize it can be inferred, though the margin is defective. The symphysial margin is slightly convex. The oval surface of the tooth is divided between raised portions of dentinal substance and
intermediate smooth hollows. The dentinal substance, which is considered by Newton to be the representative of teeth, is arranged in a series of lamellæ, or plates, near the anterior beak of the tooth; but the larger number of teeth further back are composed of small tubes, generally perpendicular to the surface, around which the dentinal substance is deposited. The large central tooth has this construction. The teeth vary considerably in outline in the several specimens, and the jaws also offer no small variety. Compared with the English Gault specimens, this one is longer from front to back in proportion to the breadth from the symphysis to the opposite margin. In this respect it also differs equally from the examples from the Anuri Bluff beds in New Zealand.

Some specimens of smaller size also occur in the collection at the Lund University; they are imperfect, and the specific characters not well preserved. The specimen represented by fig. 14 may be a part of the pre-maxilla, and the one forming the subject of fig. 15 the anterior portion of the mandible. The structure of both is open and porous; the external surface is hard, smooth, and somewhat polished; the inner surface presents a more or less granulated appearance, due probably to the calcification of the extremities of the tubes forming the dentinal surface.

**Formation and Locality.**—Étage Sénonien, No. 2: Oppmanna; Étage Sénonien, No. 1: Köpinge (figs. 12, 13). Sénonien (zone with *Actinocanax mammillatus*, Nills.): Ifö; Ignaberga (figs. 14, 15).

**Ex coll.**—Geological Museum of the University of Lund.

---

**Order.**—**GANOÏDEI.**

**Family.**—**PYCNODONTIDÆ.**


This genus is distinguished by the teeth being hollow in the centre of the crown (not due to attrition), and the elongated teeth being raised towards each
extremity. Teeth of the upper jaw in five rows; median row large, transversely elliptical, side rows with small roundish or oval teeth. Each ramus of lower jaw with three rows of teeth; outer row small and round; middle row somewhat larger, transversely oval; inner row large, very broad, but short, elliptical, smooth, faintly arched, or flat. Cutting-teeth chisel-shaped.

Zittel has reconstituted the genus Coelodus ("Handbuch der Paläontologie," vol. iii., p. 1., p. 249), and along with the species described by Heckel has included all those teeth previously described as species of Gyrodus and Pycnodus, possessing the characters given above, amongst others the types of a number of teeth occurring in the Swedish Cretaceous rocks, which Agassiz described as *Pycnodus subclavatus* from the Maestricht beds.

*Coelodus (Pycnodus) subclavatus*, Agass.

(Pl. xlii., figs. 16–18.)

A number of teeth in the collections from Stockholm and Lund may be relegated to this genus. The largest tooth is slightly imperfect, one extremity being broken. The part preserved is 0.023 m. in length, and 0.007 m. in breadth; it is thick and massive; surface of the crown smooth; subclavate in outline. A slight fold of the enamel extends round the base of the crown. Under surface hollow and rough, for attachment to the jaw. Other specimens are smaller, having a length of 0.017 m.

A group of five teeth (fig. 17) from the right ramus of the lower jaw exhibits three large teeth from the inner row, and a portion of the fourth, and a smaller one from an outer row. They are attached to a portion of the jaw having the ordinary open, spongy texture.

Two small, round teeth, apparently belonging to the same species, have been found in the Faxe or Coralline limestone.

*Formation and Locality.*—Étage Sénonien Superieur: Köpinge. Étage Sénonien Inferieur: Ignaberga; Faxe, Coralline limestone.

*Ex coll.*—Riksmuseum, Stockholm; University Museum, Lund.
Sub-Class.—TELEOSTEI.

Order.—ACANTHOPTERYGII.

Family.—BERYCIDEÆ.


Body compressed, more or less oval in outline; abdominal cavity deep; head large in proportion to the size of the body; orbit large; opercular bones serrated; vertebral column strong; dorsal fin with five or six spinous rays, strong, and widely separated. Anal fin has three spinous rays, supported by a strong interspinous process, which reaches nearly to the vertebral column. Scales large, strongly connected, but not coarsely punctured. Lateral line begins on the abdominal surface, near the tail, and passes over the vertebral column forward. It consists of arrow-shaped scales (von der Marek).

This genus is distinguished by the spinous and soft rays of the dorsal fin being continuous without intermission; in this respect it is separated from the genera Holocentrum and Myripristis, in which the spinous and soft rays form two separate fins. Agassiz* founded the genus on specimens of fish from the Chalk of Westphalia, which he named Hoplopteryx antiquus. I have on a previous occasion shown that some of the species associated with the genus Beryx † belong to Hoplopteryx (B. superbus,‡ Ag.; B. zipeii,§ Ag.; and B. Syriacus,|| Pictet & H.), and Mr. A. Smith Woodward¶ has since adduced sufficient evidence to prove that Beryx lewesiensis, Mantell (= B. ornatus, Agass.), should also be placed in the genus Hoplopteryx.

Hoplopteryx lundensis, Davis.

(Pl. xliii., figs. 1–3.)

Several specimens of this species occur in the Lund Museum. The matrix is a soft friable chalk, and the fossilized remains partake very much of the same

---

* "Poiss. Foss.," vol. iv., p. 131, pl. xvii., figs. 6–8.
‡ "Foss. Sussex," p. 372, pl. xxxvi., fig. 5.
§ "Rech. sur les Poisson Foss.," vol. iv., p. 120, pl. xv., fig. 2.
character, so that where the specimens are not fragmentary, from the breaking of the chalk, they are in few instances well preserved. The one represented on the plate indicated above has a length from the snout to the base of the tail of 0·205 m., and the tail, which is not well represented on this or any of the other specimens, is about an additional 0·04 m., which makes a total length of 0·245 m. The greatest height, in front of the dorsal fin, is 0·065 m.; thence the body diminishes in height to the peduncle of the tail, which is about 0·025 m. in height. The form of the body is an elongated oval, the posterior part tapering more rapidly than the anterior.

The head has a length of 0·08 m., and the height is 0·06 m. behind the orbit. The mouth is large, with a wide gape. The pre-maxillary (p. mx.) is 0·025 m. in length, dilated in front, and triangular behind. It bears a large number of small, pointed, villiform teeth, slightly larger near the anterior extremity than those behind. The maxilla (mx.) is long, anteriorly slender, but largely expanded towards its distal extremity. It has no teeth. The anterior extremity of the maxilla is attached to the vomer, and in the specimen (fig. 2, vom.) the anterior portion of this bone is shown to bear teeth. The mandible (mn.) is large and of robust proportions; the dentary (d) bears teeth similar to those of the pre-maxilla. Its internal surface, exhibited by a fracture of the bone, is deeply channelled, for the accommodation of the Meckel's cartilage; the articular portion of the mandible is deep, and at its lower posterior extremity is a small bone which is probably the angular. Above this the articular portion terminates in a coronoid process, extending upwards, at right angles to the base. The orbit (or.) is large, and occupies a forward position above the posterior extremity of the jaws. The bones forming the orbit, except the pre-orbital (fig. 1, p.-or.) are not well defined; neither can the elements composing the frontal or occipital regions of the head be very clearly distinguished. The frontal bones are shown in the specimens represented by all the figures, and those forming the upper posterior portion of the head in figs. 1 and 2. The arrangement of the bones composing the opercular covering is exhibited by figs. 1 and 3. The operculum (op.) is large, with a triangular posterior margin; it was probably thin, and for this reason is not well-preserved. It enveloped a portion of the body covered with scales. The sub-operculum (s.-op.), attached to the lower extremity of the operculum, is a semi-triangular bone, with a rounded inferior margin. The pre-operculum (p.-op.), is best preserved in specimen fig. 3. It is a long bone, shaped like a boomerang, with a sharp inclination forward on the anterior margin, at about one-third of its height; the posterior margin is finely serrated. The inter-operculum (figs. 2 and 3, i.-op.) is an oblong bone, the upper margin concave, whilst the inferior one is convex; both this and the pre-operculum are thicker and stronger bones than the remaining components of the gill-covers. The head represented by fig. 3 exhibits
the position and sequence of the mandibular suspensorium composed of the
hyomandibular (hyo.), the symplectic, the quadrate, and the metapterygoid,
the latter connecting the suspensorium with the pterygoid and the entopterygoid. The hyomandibular (hyo.) is largely expanded in its upper portion; its lower portion is contracted and partially hidden by the pre-operculum; joined to the hyomandibular in descending series is the symplectic or mesotympanic (sym.), which connects with the quadrate (qu.), to which the lower jaw is attached. The metapterygoid (mpt.) is a large, flat bone filling the space between the hyomandibular, the symplectic, and the quadrate, and connects them with the pterygoid (pt.) and the entopterygoid (ept.). The pterygoid is joined at its anterior extremity to a bone, which increases in size forwards, and which is probably the palatine (pal.). Attached to this bone are numerous teeth similar to those of the pre-maxilla. The palatine is also exhibited by the specimen represented by fig. 2, and on this also small teeth may be distinguished. The branchiostegals are exhibited in fig. 1.; they are long, curved bones, tapering at the distal extremity to a point.

The spinal column consists of thirty vertebrae, of which sixteen are caudal. The vertebrae are large and robust, 0·007 m. in height under the anterior rays of the dorsal fin, and 0·006 m. in length. Large haemal and neural spines, with forked bases, are attached to the vertebrae. Connected with the haemal spines, inter-spinous bones support the anal fin; whilst more numerous inter-spinous bones connect the neural spines with, and support, the dorsal fin. The ribs are long, and of considerable strength. A short distance below the vertebral column the ribs are crossed by a series of stylets or epiplural bones 0·015 m. in length.

The dorsal fin commences immediately over the scapular arch, and extends a distance of 0·09 m. along the dorsal surface. It is separated from the caudal fin by a space of 0·03 m. The anterior portion of the fin consists of a series of spinous rays, ten in number; the sixth from the head is the largest, being 0·025 m. in length, those before and behind diminishing gradually in size; the most anterior ones are short, rudimentary rays. All the rays are thick and strong, sharply-pointed, and inclined, with a slight curvature, backwards. Eight or ten articulated rays succeed without intermission the spinous ones; they are longer than the spinous rays, and divided towards the distal extremity into filaments. The anal fin commences opposite the anterior rays of the soft part of the dorsal fin, and extends backwards to a length of about 0·04 m., and appears to be separated from the base of the caudal fin by 0·03 m.; but this part of the body is not well preserved. The anterior rays of the anal fin, apparently three in number, are spinous; the posterior one is longest, equally strong and similar in form to the spines of the dorsal fin. The anal fin spines are supported by strong inter-spinous rays, widely expanded at the distal extremity, where attached to the fin rays.
The articulated rays diminish in length posteriorly, and are divided by repeated bifurcations similar to those of the dorsal fin. The caudal fin is not well preserved in any of the specimens; the one figured on Plate xlili. is the best. The lower lobe consists, apparently, of eight or nine strong articulated dichotomizing rays, connected with the vertebral column by a hypural bone, but their length cannot be determined; the upper lobe of the tail appears to have had a similar number of rays. The body of the fish is split down the middle, and consequently the pectoral fins are not exhibited, but their position may be indicated by a number of ridges showing through the scales almost midway between the dorsal and ventral surfaces. The ventral fin is supported from the scapular arch by a largely-expanded pubic bone. It is situated on the ventral surface, immediately under the posterior margin of the gill-cover. The anterior ray is spinous, with a length of 0·025 m., it is thick, and sharply-pointed. The number of fin-rays cannot be determined, but the fins were of large size.

The scales are of medium size, the height of those situated behind the gill-covers being 0·004 m. The posterior margin is circular, and slightly imbricated. The surface is ornamented with striations, running more or less parallel with the axis of the body. The direction of the lateral line (lat.) is indicated by series of foramina, which occur on alternate scales along the superior portion of the body.

This species is readily distinguished from any previously described by the number and position of the spinous rays of the dorsal fin, the number of vertebrae, together with the size of the scales. The scales of Hoplopteryx zippei, Agassiz, are not known; those of H. syriacus, P. & H., and H. oblongus, Davis, from the chalk of Mount Lebanon, are much larger than those of the Swedish fish; the scales of H. superbus, Dixon, are also large. In H. syriacus there are six spinous rays in the dorsal fin, and its anterior ray is inserted, after a considerable interval, behind the head. H. zippei, Ag., has five spinous rays, which are inserted immediately behind the occiput; the number of vertebrae is about two-thirds that of the species now described. H. oblongus is possessed of six or seven dorsal rays, and its vertebral column consists of thirty-two vertebrae.

Formation and Locality—Étage Danien (zone with Anancites sulcatus, Goldf.): Saltholm Limestone; Limhamn, Scania.

Ex coll.—Geological Museum, Lund University.

Hoplopteryx, sp.

(Pl. xlii., figs. 19, 20.)

A number of detached scales occur in the Lund Museum from the chalk of Limhamn. They have a transverse diameter of 0·025 m., and the length, antero-
posteriorly, is 0·018 m. The anterior margin is nearly straight, the upper and lower margins slightly convex, whilst the posterior one is more or less crenulated. The scales appear to have been very thin near the posterior margin, and consequently easily broken. Most of the specimens are imperfect. The surface is striated, the striations extending parallel with the upper and lower margin of the scale, whilst a second series radiate from the middle of the anterior surface of the scale, and extend to the posterior margin (fig. 19). Other scales are more or less oval in outline, with concentric rings over the greatest portion of the surface, the posterior part of the scale, which was uncovered by succeeding ones, being striated (fig. 20). The greatest diameter is 0·03 m.

These scales appear to resemble most closely those of *Hoplopteryx lewisiensis*, Mant. (*Beryx ornatus*, Ag.), and, whilst there is insufficient material to form a species, there can be no hesitation in including them in the genus *Hoplopteryx*.

**Formation and Locality.**—Étage Danien (zone with *Anancites sulcatus*, Goldf.): Saltholm Limestone; Limhamn, Scania.

*Ex coll.*—Geological Museum, Lund University.

*Hoplopteryx minor*, Davis.

(Pl. xlv., figs. 3 and 4.)

A number of specimens of a small species of Hoplopteryx from the chalk of Limhamn occur in the collections at the Riksmuseum at Stockholm. They are all imperfect, and afford only a small amount of information as to their characters and structure. The head, and a portion of the vertebral column, is all that is preserved. The head, from the tip of the snout to the posterior margin of the gill-cover, is 0·05 m., and the height of the head 0·04 m. The orbit was probably large. The gill-cover consists of the pre-operculum (*p. op.*), a long bone, with a crenulated margin; the operculum (*op.*) is imperfect, the anterior margin slightly concave, the upper margin rounded, and the remaining part along the posterior margin inclined to the inferior anterior extremity, so as to form an irregular triangle. The inter-operculum is not preserved; but a detached bone has the appearance of being the sub-operculum (*s. op.*). The mandible (*m.*) is attached at its posterior extremity to a triangular bone, the quadrate (*q.*). The mandible is strong, deep behind, the dentary portion bearing a number of small teeth. The maxilla (*mx.*) and pre-maxilla (*p.-mx.*) may also be distinguished, but the dentition of the latter is not defined. Other bones may be distinguished on the anti-orbital and inter-orbital regions of the head.

A portion of the vertebral column is preserved. It extends to a distance of
0·035 m. behind the occiput, and is 0·025 m. in length. The vertebrae are 0·005 m. in length, and a little less high than long.

The specimen represented by fig. 4 is in all probability a smaller example of the same species. A number of spinous rays are preserved on the dorsal surface. The anterior ray is located a distance behind the occiput, equal to the length of the head. The fin-rays are supported by inter-spinous bones. The ribs are long and moderately strong. A series of epiplural spines extend transversely to the ribs, parallel with, but separated a short distance from, the vertebral column.

This species does not agree with any of those previously described, as far as its imperfect remains can be deciphered.

*Formation and Locality.*—Étage Danien: Limhamn, Scania.
*Ex coll.*—Riksmuseum, Stockholm.

**Genus. Berycopsis. Dixon.**

This genus was proposed by Professor L. Agassiz for a fish from the Chalk of Sussex. It has much resemblance to the genus Beryx, but differs from it in the absence of pectinations on the free margins of the scales. The scales are of moderate size, thick, and smooth, or only ornamented with delicate radiating lines. The fin-rays of the dorsal and anal fins are robust. The rays of the dorsal fin are continuous with the preceding spinous rays, six or more in number, shorter than the soft rays, but stout and strong. Pelvic fin with a spinous ray, and seven or more articulated rays. Anal and caudal fins unknown.

The only species known is *B. elegans*, Dixon, from the middle chalk, Clayton, of which the type specimen is in the Brighton Museum. There are others in the Natural History Department of the British Museum, South Ken sington.

**Berycopsis lindstomi, Davis.**

(Pl. xliv., figs. 1, 1u.)

A large and unique specimen, which apparently belongs to this genus, occurs in the collection of the Geological Survey at Stockholm. The length of the part preserved is 0·23 m.; but the fish is devoid of the caudal fin, and the head is somewhat dislocated, and badly preserved. The body is deep, measuring 0·10 m. in front of the dorsal fin. The dorsal and anal fins are not preserved, except the remains of a single spinous ray of the dorsal; but the presence of a long dorsal fin is indicated by a long series of inter-spinous rays, which, no doubt, afforded
support to the fin. Judging from a similar analogy, the anal fin occupied a length much shorter than the dorsal, and was situated in close proximity to the caudal fin. The caudal fin was probably large and powerful, the bases of strong rays surrounding the extremity of the vertebral column affording evidence to that extent, though the fin itself is absent.

The front part of the body, with the head, is displaced, and this renders the identification of this part of the fish obscure. The operculum on the left side has been squeezed down, and with it the scapular bones supporting the pectoral fin. The pectoral fin, originally occupying a lateral position, is represented on this specimen depressed to a position on the ventral surface. It was large, and apparently composed of a large number of rays. A second fin is represented; it is of considerable size, and may be the ventral fin attached to the opposite side of the body.

The whole of the surface of the body is covered with scales; they are thin, closely overlapped, and of medium size; a few scales on the ventral surface are tolerably perfect; the exposed part is 0.004 m. in height; the posterior border is circular, with a minute imbrication, determined with difficulty by a strong magnifier, along the margin; the surface of the scale has a concentric arrangement of striae, roughly parallel with the margin (fig. 1a). The anterior portion of the scale is hidden beneath the posterior margins of the preceding scales. The majority of the scales are crushed and imperfect. The vertebral column is distinctly visible beneath the scales, especially the posterior part. It consisted of about forty vertebrae, 0.05 m. in length; the height slightly exceeding the length in the median part of the body; nearer the tail the vertebrae are considerably shorter. They are less constricted in the median part than are the vertebrae of Hoplopteryx, and the articulating surfaces are supported by numerous buttresses, extending from one to the other. To the vertebrae are attached strong hæmæl and neural spines, which in turn afford support to inter-hæmæl and inter-neural spines. These can be readily distinguished beneath the scales. The ribs are comparatively long, reaching two-thirds the distance from the vertebrae to the abdominal margin.

This specimen is related to Berycopsis elegans, Dixon,* from the chalk of Sussex.


Formation and Locality.—Étage Danien (zone with Anancites sulcatus): Saltholm Limestone; Linhamn, Scania.

Ex coll.—Riksmuseum, Stockholm.
Family.—**TRICHIURIDÆ.**


*Enchodus, sp.*

A small number of teeth, apparently belonging to the genus *Enchodus*, have been found in the Upper Senonian beds characterized by the presence of *Belemnites mucronatus* at Köpinge. The largest of the teeth is 0·015 m. in length, with a diameter at the base of 0·003 m. The surface of the teeth is finely and regularly striated longitudinally; the tooth is compressed, and a sharp edge is produced along each lateral margin. The teeth are broken off at the base, where they have probably been ankylosed with the jaw. Other specimens, two-thirds the size of the above, exhibit similar characters, one of them being especially well-developed along the lateral margins, which extend in a knife-like process on each side.

The teeth are probably those of *Enchodus halocyon*, Agassiz, (*levisiensis*, Mantell) ("Poiss. Foss.," vol. v., pt. i., p. 64, pl. xxv. c., figs. 1–16); but there is scarcely sufficient preserved to satisfactorily determine the identity.

*Formation and Locality.—*Étage Sénonien Supérieur; Köpinge.

*Ex coll.—*Riksmuseum, Stockholm.


Body compressed and elevated; head large; snout prominent; scapular arch composed of bones of great length and thickness.

*Bathysoma lutkeni*, Davis.

(Pl. xlvi., figs. 1–7.)

A fine series of specimens from the Saltholm Limestone occur in the Museum of the University of Lund and in the Mineralogical Museum of the University of Copenhagen. They have all been obtained from Limhamn, in Scania. The fish is compressed laterally; it reaches a length of about 0·10 m., and the height of the body immediately behind the scapular arch is equal to four-fifths of the length; or, if the measurement be taken from the anterior extremity of the mandible to the peduncle of the tail, the height of the body is equal to the length.
The head is large, and absorbs quite two-fifths of the entire length. The facial contour forms a prominent feature. The body of the fish rapidly diminishes in size towards the tail. It is to be regretted that no specimen is sufficiently well preserved to exhibit the entire form of the fish; but a more or less complete idea can be obtained by comparing the several specimens, and taking the aggregate result. (Pl. xlvi., fig. 7.)

The head is produced anteriorly, and terminates in a protruding snout; the posterior margin, formed by the operculum and a thin median bone extending from the supra-occipital region forwards, is more or less circular in outline. The orbit is situated in the posterior moiety of the head, and is somewhat high; it is large and encircled by bones. In front of the orbit a large but thin bone may be distinguished, which represents the pre-orbital; its posterior boundary is formed by the margin of the pre-operculum. A straight bone, probably the para-sphenoid, extends across the base of the orbit. The maxilla is long and somewhat slender, and is divided by an oblique suture from the pre-maxillary. The mandible is large, high in front, diminishing in size backwards, and extending to a position beneath the orbit, where it is articulated with the quadrate. No teeth can be distinguished on any of the specimens, either on the upper or lower jaws. The inter-orbital bones are not well preserved on any of the examples; but fragmentary outlines exist which indicate that the frontal and occipital bones are produced, and form a thin median bony crest, extending above the orbit backwards. The operculum consists of four elements: the pre-operculum is a triangular bone, with a concave anterior margin, pointed above, and rounded below; deep ridges extend from the pointed upper margin, and radiate towards the circular inferior margin. Behind and above the pre-operculum is the operculum; it is rounded behind, and channels radiate over its surface from the upper anterior margin, where it joins to the pre-operculum. It is the largest of the opercular bones. The sub-operculum is a long bone, extending parallel with the operculum, and situated immediately behind it. The inter-operculum is also long and narrow, extending from the sub-operculum to the anterior extremity of the pre-operculum. Other bones of the head may be distinguished, but not with sufficient distinctness to be readily identified.

The vertebral column consists of thirty vertebrae, of which ten are abdominal, and the remainder caudal. The vertebrae nearest the head are equal in height to the length, but towards the tail they become gradually narrower, so that the height is greater than the length. The centra are biconcave, and the median external surface is much constricted. The apophyses of the vertebrae are strong and afford attachment to haemal and neural spines, the former of great length. The upper part of the body is not in any instance well preserved; but the neural spines are seen to have an elevation of 0·02 m., and the fragmentary remains of
inter-neural spines are present. The haemal spines are longer than the neural. Attached to them are inter-haemal bones of great strength; their anterior and posterior margins are expanded, so that the series form an almost continuous bony mass. The anterior inter-haemal bones are more numerous than the haemal spines. There are two, and in the anterior part three, inter-hemals to one haemal. The first haemal and inter-haemal are very thick and strong, and are each of so great a length that they overlap to a considerable extent. The lower extremity of the inter-haemal is widely expanded, and with a convex curvature extends forward to such an extent as to form an attachment with the styliform process of the post-clavicle and other elements of the scapular arch. With so strong a basis for support, it will naturally be inferred that the anal fin was large, with anterior spinous rays, but no trace of the actual fin remains on the specimens under examination. Nearer the caudal fin both the haemal and neural spines and their auxiliaries become rapidly smaller. The caudal fin is attached by a short peduncle; the terminal vertebra supports an expanded triangular hypural bone, to which the rays of the tail are attached. Like the dorsal and anal fins, the caudal is not well preserved; but one specimen shows that the caudal was composed of numerous finely-articulated fin-rays. The ribs were short and attenuated.

The scapular arch exhibits a peculiar modification, adapting it to the great depth of the body. The upper members of the series are hidden by the overlying bones of the operculum. Immediately behind the extremity of the mandible, the clavicle extends with a gentle curvature backwards and downwards, and at its extremity joins a styliform process of the coracoid. Attached to these bones is the pubic, a large bone, widely expanded at the base, but tapering upwards to a pointed extremity. The clavicle is a strong bone, with an expansion of the upper surface. A very long and slender post-clavicle, its attachment at the upper end hidden by the gill-covers, descends in the form of a styliform process, and assists in giving support to the large pubic bone, to which the ventral fin was doubtless attached, but nothing remains to indicate its size or form.

Amongst existing fishes the Sun-fish, Lampris luna, is a pelagic fish, which attains to a great size; it is found commonly near Madeira, and from thence northwards in the Atlantic. Its skeleton exhibits a very large development of the scapular arch, and in many respects it closely resembles the fossil. The clavicle is very long and dilated, and the post-clavicle, slightly expanded at the top, descends in the form of a long styliform bone. Similar characters, but less distinctly specialized, may be observed in the skeleton of Capros aper, a Mediterranean fish, sometimes found on the coasts of England.

Some of the species of the fossil Gastronemus, most especially G. rhombeus, Ag.,*  

* "Poissons Fossiles," vol. v., p. 20, pl. ii., figs. 1, 2.
present some features of great similarity to the species now described. The body is elevated and compressed; the scapular arch large and well developed; ribs small and insignificant, and the inter-spinous bones large and expanded. The vertebral column is more massive and stronger in proportion to the size of the fish; it is composed of twenty-four vertebrae, whilst in the species now described there are thirty. Gastronemus occupies a position intermediate between the forms represented by Vomer* and the species now described, with a strong inclination towards Vomer. Both these genera have the same number and distribution of the vertebrae; but in this species the vertebral column is smaller and less robust, whilst the number of its constituents is larger. The pectoral fin is large in Vomer and Gastronemus, but in this genus is comparatively small. The greatest and most characteristic divergence will be found, however, in the character and composition of the elements of the scapular arch.

**Formation and Locality.**—Saltholm Limestone; Étage Danien (zone with Anancites sulcatus, Goldf.): Limhamn, Scania.

**Ex coll.**—University Mineralogical Museum, Copenhagen; University Geological Museum, Lund.

---

**Order.**—**Physostomi.**

**Family.**—**Clupeidae.**

**Genus.** *Clupea.** LINN.

Body compressed, with the abdomen serrated, the serrature extending forwards to the thorax. Scales of moderate or large, rarely of small, size; upper jaw not projecting beyond the lower; cleft of the mouth of moderate width; teeth, if present, rudimentary and deciduous. Anal fin of moderate extent, with less than thirty rays; dorsal fin opposite to the ventrals; caudal forked.

*Clupea lundgreni,* **Davis.**

(Pl. xlv., fig. 5.)

A unique specimen of this genus occurs in the Museum of the University of Lund. It is unfortunately imperfect. The part of the body preserved includes

* "Poissons Foss.,” vol. v., p. 28, pls. v. and vii.
the base of the caudal fin, the anal fin, a portion of the dorsal fin, and about forty vertebrae, of which sixteen are caudal. The length of the spinal column, which is preserved, is 0·09 m., and the total length of the fish, as indicated by this portion, was probably 0·15 m. The vertebrae are as high as broad, bi-concave, and much constricted medially. Each vertebra supports a hæmal and neural spine, long and slender, and as nearly as possible equal in length. Portions of the anal fin are preserved, but not sufficient to by so indicate precisely its form and size. The dorsal fin is represented by twelve fin-rays; the posterior rays are 0·05 m. in advance of the caudal fin. Opposite the anterior rays of the dorsal fin the ribs commence. They are strong and a considerable length. The tail is imperfect, only the base being preserved. No scales can be identified.


Family.—**HOPLOPLEURIDÆ**, Pictet.


"Body generally with four series of sub-angular scutes, and with intermediate scale-like smaller ones. One (?) dorsal only; head long, with jaws produced."

The family Hoplopleuridæ was established by Pictet for fishes which were devoid of scales properly so-called, but which are protected on the back and sides by rows of scutes. The head is long and the jaws provided with pointed teeth of unequal size. The bones of the head are frequently sculptured or granulose. The genera associated in this family by M. Pictet are Dercetis, Agassiz;* Sauroramphus, Heckel;‡ Eurypholis, Pictet;§ Pelargorhynchus, Von der Marck;‡ Leptotracelus, Von der Marck;|| Plintrophorus, Günther.||| The fishes included in the genus Dercetis were considered by Agassiz to resemble the sturgeons in the arrangement of the dermal scutes, and were grouped amongst the Ganoids. Heckel held the same opinion with respect to the position of Sauro-

|| "Fossile Fische, Krebse und Pflanzen aus dem Plattenkalk der jüngsten Kreide in Westphalen."—Palaeontographica, vol. ix., p. 61, pls. xi., xii., fig. 3. 1863.
¶ "Desc. of a New Foss. Fish from the Chalk."—Geol. Mag., vol. i., p. 114, pl. vi. 1864.
ramphus, and Von der Marck also places the genera Pelargorhynchus and Leptotrachelus amongst the Ganoids, but regards Ischyrocephalus as a Teleostean. A careful review of the whole of these genera, assisted by additional specimens of Leptotrachelus and Eurypholis discovered in the chalk of Mount Lebanon, convinced M. Pictet that they formed a group naturally associated, especially by the great analogy afforded by the peculiar arrangement of the series of scutes, and that they formed a family of the Teleostceans, to which he gave the above name.

**Genus. Dercetis.** Agassiz, "Rech. sur les Poissons Fossiles," vol. ii., pt. ii., p. 258, pl. lxvi. a, figs. 1, 2, 5, 6, 7, 8 (non figs. 3, 4).


The genus Dercetis was instituted by M. Agassiz, in concert with Count Münster, for fossil fishes, with elongated body and head, the latter prolonged into a straight beak. The upper jaw a little longer than the lower, both being armed with elevated conical teeth, alternating with others smaller. The spinal column composed of robust vertebrae, longer than high, and constricted in the middle. Pectoral fins large, the ventrals small and composed of few rays. The dorsal fin is described as extending along nearly the whole surface of the back, the anal being about half the length of the dorsal, and finishing at the same point. The caudal short and slightly forked. The sides of the body are furnished with three rows of scutes, extending the whole length, and resembling those of the sturgeon. The scutes are heart-shaped, osseous, with a granular external surface, and surmounted by an angular median projection. The species described as pertaining to this genus are _D. elongatus_, Ag., from the chalk of Lewes, England, and _D. scutatus_, Münst. and Ag., from the Chalk of Westphalia. Mr. A Smith Woodward* has already pointed out that the English specimens are entirely devoid of fins; and it may consequently be presumed that the description of the long dorsal and anal fins was taken from the Westphalian species. It may further be inferred,

that such being the case, the specimens were identical with those found in the same strata, which have since been described by W. Von der Marck under the generic name of Pelargorhynchus, which possesses a very long dorsal fin, and an anal similar to the one described by Agassiz.

In 1850, F. J. Pictet described three species of Dercetis from the Chalk of Mount Lebanon. Two of these, namely, *D. triqueter* and *D. tenuis*, were subsequently transferred in the "Nouvelles Recherches sur les Poissons Fossiles du Mont. Liban." (1866), to the genus Leptotracchelus, Von der Marck; and the addition of specimens in a better state of preservation proved that the *D. tenuis* was derived from the cervical region of *D. triqueter*. The third species *Dercetis linguifer*, Pictet, known only from a fragment of the body, very imperfectly preserved, was still doubtfully retained as representing the genus Dercetis in the Chalk of Lebanon.

In the description of the fossil fishes of Mount Lebanon* published in 1887, it is remarked that since the year 1866 a considerable number of specimens of Leptotracchelus have been obtained, and these differ much in size as well as in the details of the form of the scutes; and there can be no doubt that the figure given by M. Pictet (op. cit., pl. ix., figs. 7, 8) is that of a portion of the body of a large fish of the genus Leptotracchelus, and that it is the same species as those already included in the species *L. triqueter*, Pictet and Humbert. Since the above was written I have had opportunities of examining the originals, in the Mantell collection at the British Museum (Natural History Department), figured by Professor Agassiz, and I am convinced that they are the same genus as the fish-remains described as Leptotracchelus from Mount Lebanon.† This being so, it becomes a question of synonymy, and as Dercetis was established about twenty years before Leptotracchelus, it follows that the latter must be considered as a synonym of Dercetis, Agass. The Lebanon fish-remains included under *Leptotracchelus triqueter*, Pictet and Humbert, will revert to the original designation of Pictet, and be again *Dercetis triqueter* (including *D. tenuis*, Pictet, and *D. linguifer*, Pictet), and the species *Leptotracchelus hakelensis*,‡ Pictet and Humbert, and *L. gracilis*,§ Davis, will be *Dercetis hakelensis* and *D. gracilis*.

Dr. Anton Fritsch describes specimens from the chalk of Wehlowitzer Pläner, near Prague, which he has named *Dercetis reussii;‖ Fritsch. The remains are

‖ "Die Reptilien und Fische der Böhmischen Kreideformation," p. 20, pl. ii., fig. 8; pl. iv., fig. 1; pl. x., figs. 1, 6. 1878.
fragmentary, consisting of the head and portions of the vertebrae, imperfectly preserved. They do not present sufficiently characteristic features for full comparison with the species already, or presently to be, described.

For the opportunity of studying the specimens which I now proceed to describe I am indebted to the courtesy and kindness of Dr. W. Dames of Berlin, to whom Dr. Lundgren had entrusted them, along with others, for description, previously to my visit to the Lund Museum. In order to render this memoir as complete as possible, Dr. Dames readily consented to place the fish-remains at my disposal, retaining the bird-remains which form the new genus Scaniornis, Dames.*

0·035 m. in length, extends between the occipital and the anterior vertebrae, and represents the scapular bones (sc.). The operculum probably occupied this area, but has entirely disappeared, unless the fine bone (op.) be a transverse section of it.

The spinal column is represented by eighteen vertebrae. A space between the head and the first vertebra preserved forms an interval requiring six or seven vertebrae to fill it. The vertebrae are 0·005 m. in length and 0·006 m. in height, in this respect differing much from those of Deretis (Leptotrichelus) triqueter, Pict. & Humb., from Mount Lebanon, in which the vertebrae near the head are twice as long as high. The vertebrae are constricted in the middle, and well ossified. (Pl. xl.v., fig. 1 c.)

The scutes have, at least, two forms; one represented by fig. 1 a is probably from the median lateral line; the front consists of a pointed prolongation of the median axis; on each side are aliform expansions of the surface, whilst the posterior margin is made up of a pair of projections, one on each side the median line of the scute. The pointed prolongation of this scute may have been perforated by the canal of the lateral line. Mr. A. Smith Woodward has figured an example of a scute of Deretis elongatus, Agass.,* from a flint-nodule found in the Chalk of Norfolk, England, which exhibits this peculiarity very beautifully. A second form on the specimen from Limhamn is represented by fig. 1 b, and is from the dorsal surface; it varies considerably from the lateral scute, and, so far as can be observed, extends from the median dorsal line, with the point towards the lateral line, a corresponding scute opposing it, and extending in the opposite direction. The two series of opposing scutes in the example figured may be seen to some extent enveloping the vertebral column, and extending from it on each side, with the point outwards.

The form and character of the scutes, together with the vertebrae, separate this species from those previously described, and I indicate it specifically by the name of the district from which it was obtained.

Formation and Localities.—Étage Danien: Saltholm Limestone: Limhamn, near Malmö, in Schonen.

Ex coll.—Lund University Geological Museum.

LIST OF SPECIES, WITH THE LOCALITIES IN WHICH THEY OCCUR.

<table>
<thead>
<tr>
<th>NAME OF SPECIES</th>
<th>Senonian Superior</th>
<th>Senonian Inferieur</th>
<th>Danien</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myliobatis sp. (?), Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ptychodus decurrens, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; mamillaris, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notidanus microdon, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; dentatus, A. S. W.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scyllium planum, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scaeanorhynchus tenalis, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; latus, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; gracilis, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Odontaspis acuta, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; acutissima, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; faxensis, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; kopingsensis, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oxyrhina mantelli, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; lundgreni, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; zippel, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; conica, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lamna elegans, Agass.,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&quot; incurva, Davis,</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### List of Species, with the Localities in Which They Occur—continued.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Osteus appendicularis, Davis</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Limax</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>O. m.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. h.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H. h.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H. s.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>B. g.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S. h.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>S. s.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>K. r.</strong></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Davis—On the Fossil Fish of the Cretaceous Formations of Scandinavia.**
PLATE XXXVIII.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XXXVIII.

Figure
1, 2. Pychodus decurrens, Agass.
   2. Oretorp. Ex coll.—

   Annetorp. Ex coll.—Riksmuseum, Stockholm.

4-7. Notidanus microdon, Agass.
   4, 5. Teeth of the upper jaw. 4a. Enlarged.
   6, 7. Teeth from lower jaw. 6a. Enlarged.

   Faxe. Ex coll.—Zoological Museum, University, Copenhagen.

9. Scyllium planum, Davis, §.
   Terkild-Skov. Ex coll.—Mineralogical Museum, University, Copenhagen.

10-13. Scapanorhynchus tenuis, Davis.
   10. Tooth; a. internal surface, enlarged §; b. side view.
   11. Median tooth; a. internal surface, enlarged §.
   Oretorp. Ex coll.—Riksmuseum, Stockholm.

14-17. Scapanorhynchus latus, Davis.
   14. Anterior tooth; a. external surface; b. side view; c. internal surface.
       Enlarged §.
   15, 16, 17. Other specimens.
   Oretorp. Ex coll.—Riksmuseum, Stockholm.

18-20. Scapanorhynchus gracilis, Davis.
   18a. Internal surface; b. side view; c. external surface. Natural size.
   Annetorp. Ex coll.—Geological Museum, University, Lund.

21-24. Odontaspis acuta, Davis. (All natural size.)
   21. a. External surface; b. side view; c. Internal surface.
   22. a. External surface; b. side view.
   22. Oppmanna. Ex coll.—
   23. Stevns. Ex coll.—Mineralogical Museum, University, Copenhagen.
   24. Faxe. Ex coll.—

25. Odontaspis acutissima, Agass.
   Faxe. Ex coll.—Mineralogical Museum, University, Copenhagen.

26. Odontaspis faxensis, Davis.
   a. External surface; b. side view; c. internal surface.
   Faxe. Ex coll.—Mineralogical Museum, University, Copenhagen.

27, 28. Odontaspis kopingsensis, Davis.
   a. External surface; b. side view; c. internal surface.
   27. Kopinge. Ex coll.—Mineralogical Museum, University, Copenhagen.
PLATE XXXIX.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XXXIX.

Figure.


1.  
   a. External surface of a median tooth;  
   b. side view;  
   c. internal surface.

1-5. Oppmann.  
   *Ex coll.*—Geological Museum, University, Lund.

6, 7. Limhamn.  
   *Ex coll.*—Riksmuseum, Stockholm.


8. Anterior tooth, external surface.

9. Anterior tooth, with the root attached, external surface.

10. Highly-curved example, external face;  
    a. side view.

11.  
    a. External surface;  
    b. side view;  
    c. internal surface.

8-14. Limhamn, Skanie.  
   *Ex coll.*—Riksmuseum, Stockholm.

   *Ex coll.*—Mineralogical Museum, University, Copenhagen.

   *Ex coll.*—Geological Museum, University, Lund.

11. Limhamn.  
    *Ex coll.*—Riksmuseum, Stockholm.

12.  
    "  
    "  
    "  
    "


14a. Side view of the same specimen.
PLATE XL.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XL.

Figure.


1a. External surface; b. side view; c. internal surface.


8, 9, 10. **Oxyrhina conica**, Davis, sp. nov.

8a. External surface; b. side view; c. internal surface. All × 3 diameters.

9. Posterior tooth.

10. Median tooth.


11. Anterior tooth; a. external surface; b. internal surface.

12. Side view of anterior tooth.

13a. External surface; b. internal surface. With lateral denticles.

14. External surface, with lateral denticle of median tooth.

15, 16. Posterior teeth.

17a. External surface; b. side view; c. internal surface.


18a. External surface; b. side view; c. internal surface.

19, 20, 22. External surface.

21, 23. Internal surface.

24a. External surface; b. side view; c. internal surface.


26. "" "" ""

*Faxe Limestone. Ex coll.*—Geological Museum, University, Lund.

27. **Vertebra of Otodus**, sp.

a. Concave surface of centrum; b. lateral surface.


28-32. **Series of Small Vertebrae**.

a. Centrum Enlarged; b. lateral views enlarged.

*Köpinge. Ex coll.*—Riksmuseum, Stockholm.

33. **Coprolite of Otodus**.

*Köpinge. Ex coll.*—Riksmuseum, Stockholm.
PLATE XLII.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XLI.

Figure.


1. Anterior tooth; *a*. external surface; *b*. side view; *c*. internal surface.
2-6. Common forms of the teeth.
7, 8. Median teeth.
2, 3, 4, 5. Faxe. *Ex coll.*—Mineralogical Museum, University, Copenhagen.

12. *Otodus limhamnensis*, Davis.

1a. External; *b*. internal surface; *c*. side view.


13a. External surface; *b*. internal surface; *c*. side view.


Faxe. *Ex coll.*—Mineralogical Museum, University, Copenhagen.
PLATE XLII.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XLII.

Figure.

1. *Section of Vertebra of Otodus, sp.*

2. " " "
   Faxe. *Ex coll.—Zoological Museum, University, Copenhagen.*

3-11. *Corax lindstromi,* Davis. *a.* External surface; *b.* internal surface.
   5-11. Ignaberga. *Ex coll.—" " " " " *

12, 13. *Ischydus brevirostris,* Newton.
   13. Köpinge. *Ex coll.—" " " " " *

   Ignaberga. *Ex coll.—Geological Museum, University, Lund.*

   Ifo. *Ex coll.—Geological Museum, University, Lund.*

16-18. *Celodus subelavatus,* Ag.
   16, 18. *Ex coll.—Riksmuseum, Stockholm.*

19, 20. *Hoplopteryx,* sp.
   Linhamn. *Ex coll.—Geological Museum, University, Lund.*

   Faxe. *Ex coll.—Mineralogical Museum, University, Copenhagen.*
PLATE XLIII.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XLIII.

Figure.


PLATE XLIV.

FOSSIL FISH OF THE CRETAEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XLIV.

Figure.

1. *Berycopsis lindstromi*, Davis.

1a. Scale from the ventral surface enlarged.

*Ex coll.*—Riksmuseum, Stockholm.
PLATE XLV.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XLV.

Figure.

1. *Dorretis limhamnensis*, Davis.
   1a. Lateral scute enlarged two diameters.
   1b. Scute from dorsal surface, enlarged two diameters.
   1c. Vertebrae enlarged.

2. *Dorretis limhamnensis*, Davis. Head of the same specimen, exhibiting the occipital arrangement of head-bones.

3, 4. *Hoplopteryx minor*, Davis.

5. *Clupea lundgreni*, Davis.
PLATE XLVI.

FOSSIL FISH OF THE CRETACEOUS FORMATIONS OF SCANDINAVIA.
EXPLANATION OF PLATE XLVI.

Figure.
1, 2. *Bathysoma lutkeni*, Davis.  
Limhamn. *Ex coll.*—Mineralogical Museum, University, Copenhagen

3, 4. *Bathysoma lutkeni*, Davis.  

5. *Bathysoma lutkeni*, Davis. Vertebrae and haemal spines of a larger example.

6. " " " Anterior one of the same, enlarged.  

TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1-25.—November, 1877, to September, 1883.  (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1-2.—August, 1879, to April, 1882.  (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1-14.—September, 1883, to November, 1887.  (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.


3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.


5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

VII.

SURVEY OF FISHING GROUNDS, WEST COAST OF IRELAND, 1890. I.—ON
THE EGGS AND LARVAE OF TELEOSTEANS. By ERNEST W. L. HOLT,
St. Andrew’s Marine Laboratory.

(Plates XLVII. to LII.)

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORGATE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.
1891.

Price Four Shillings and Sixpence.
THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

VII.

SURVEY OF FISHING GROUNDS, WEST COAST OF IRELAND, 1890. I.—ON
THE EGGS AND LARVAE OF TELEOSTEANS. BY ERNEST W. L. HOLT,
St. Andrew’s Marine Laboratory.

(Plates XLVII. to LII.)

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

LONDON: WILLIAMS AND NORGATE.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.

1891.
VII.

SURVEY OF FISHING GROUNDS, WEST COAST OF IRELAND, 1890. I.—ON THE EGGS AND LARVAE OF TELEOSTEANS. By ERNEST W. L. HOLT, St. Andrew’s Marine Laboratory. Plates XLVII. to LII., and Table.

[Read November 19, 1890.]

[COMMUNICATED BY PROFESSOR A. C. HADDON, M.A.]

These Notes comprise a series of Observations on Teleostean ova (and larvæ hatched therefrom, on board) collected off the west coast of Ireland, between Aran Islands on the south and Killybegs Bay on the north, during the cruise of the “Fingal” on the Royal Dublin Society’s Survey of Fishing Grounds between the 12th of June and the 11th of July, 1890.

All observations and drawings of the living forms were, of necessity, made on board, and it may be urged, as an excuse for their incompleteness, that a ship, even in fine weather, of which we experienced little, is not the best place for microscopical study, whilst it was only possible to devote to this subject such time as could be spared from the more important duties (in view of the objects of the expedition) of examining the reproductive organs and food of the adult fishes, in addition to faunistic observations and preservation of specimens of special interest. A few further notes on the egg-capsule have been made at this laboratory from specimens brought from Ireland.

The methods used for the capture of pelagic ova were (1) towing at the surface small ring-nets of fine cheese-cloth at the sides of the vessel whilst trawling; (2) sinking larger ring-nets and a large triangular midwater-net, after Professor M’Intosh’s pattern, to a fathom or so below the surface, and allowing the ship to drift with them for a short time; (3) sinking ring-nets to various depths whilst at anchor in a tide-way; (4) trawling from the ship’s boats with a small naturalist’s trawl with muslin net; owing, probably, to some defect in the latter, this method was not very successful. The first method proved by far the most productive, and is convenient, as it can be carried on whilst the ship is trawling. It has one drawback—that one is apt to capture in the net many things not essentially
marine. The second method yields fair results, but necessitates a certain expenditure of time. It also appeared that ova were more abundant at the surface than a short distance below, on the comparatively fine days when this method was adopted. The third method was successful on one occasion in Blacksod Bay on the flood tide, the ova occurring in the surface-net.

Young fish, principally mackerel-midges (Motella) and suckers (Liparis), occurred often in the surface-nets, the latter always amongst drift weed, under which the former also appeared frequently to take shelter. Many other young fish were obtained with the naturalist's trawl with shrimp mesh, but these do not enter into the subject of this Report.

The ova were separated from the rest of the contents of the net by examination in glass tubes at sea, and were sorted, when at anchor, and the different species placed in separate vessels—individuals being further isolated when occasion required. The vessels used were shallow circular jars, or, failing a sufficient number of these, short tubes of 2½ inches by 1½ inch. Accidents were frequent in bad weather, till the vessels were placed in a large zinc tray on a swinging table in the saloon, where they were comparatively safe from upsetting, but open to the attacks of dust. A good supply of water was usually brought in from the open sea, but it was found that frequent changes of water were not beneficial.

In the case of several species only one or two individuals were obtained, which were kept alive as long as possible for observation, and, having finally died, were of little or no service for further investigation.

My best thanks are due to the Director of the expedition, the Rev. W. Spotswood Green, one of H. M. Inspectors of Fisheries, Ireland, for his unvarying kindness in assisting me to obtain specimens; and I have also to thank Mr. T. E. Duerden, of the Royal College of Science, for help in sorting the ova obtained. To Professor Haddon I am also indebted for much help in various ways. Professor Mc'Intosh, F.R.S., has allowed me to draw up this Report at this laboratory, and has enabled me, by advice and criticism, to add considerably to its value.

A number of pelagic ova were obtained which cannot be definitely referred to any species. I have, accordingly, placed them in a series of Roman numerals—I. to IX.

In the arrangement of the known forms I have followed Günther's classification. The unidentified species have no special arrangement.

My figures are not drawn to a uniform scale. I have, therefore, appended a Table to show the relative sizes of the different ova. The actual dimensions of the young fish are shown in the usual manner in the plates.
Scombridæ.

Scomber scomber (Linn.) The Mackerel.

About fifty small autumn mackerel, from the neighbourhood of Broadhaven Bay, were examined by Mr. Duerden and myself on the 20th June. We found that many of the males were ripe, whilst the females were, in various stages, approaching ripeness, with the exception of one which was fully ripe.

Day* remarks, on the authority of Dunne, that this species spawns at Mevagissey in May or June; and Cunningham† gives June and the first half of July for the Plymouth district. The period seems to extend to August in Scotch waters.‡ Sars found that spawning usually took place in the first half of July.

Trachinidæ.

Trachinus vipera (Linn.) The Lesser Weever.

(Pl. xlvii., fig. 8; Pl. xlviii., fig. 15; Pl. xlix., figs. 31, 32; Pl. l., figs. 37, 38.)

Ova, which have been identified with this species from Brook's description,§ occurred in considerable abundance in the surface-nets in Blacksod Bay on the 15th June and 11th July; in Inver Bay on the 25th, 28th, and 29th June; in Clew Bay on the 30th June; and on several other occasions in these bays.

The diameter is 1·25–1·37 mm.; the yolk is clear, colourless, and homogeneous, and there are (fig. 31) from eleven to nineteen small pale greenish-yellow oil globules (the largest .06 mm. in diameter) scattered over the upper hemisphere of the yolk. Seen by the naked eye, the globules give a dull yellowish colour to the egg, very similar to that of the common sole's egg. The egg-capsule is thin, but tough and resistant.

In flattened preparations, under a high power, an optical section shows that it is divisible into an outer homogeneous layer (fig. 8, v. m.) and an inner layer (st.) showing four or five stratifications. The two layers are of about equal thickness (fig. 8). Treated with picro-carmine, the outer layer takes only the yellowish stain, whilst the stratified part is very faintly affected by the carmine. The double nature of the egg-capsule, in this species, was observed by Brook (op. cit., p. 275), who considers the outer layer as the vitelline membrane, according to the definition

* British Fishes. Vol. i., p. 89.
of Balfour. It is doubtful whether it really represents anything more than an unusually thick lamina of the zona.* The inner layer (st.), in which Brook noticed no stratifications, is regarded by him as the zona-radiata; and he remarks that the two layers are occasionally separated by a space. I noticed an extreme opacity in the capsule of an apparently healthy egg, which may, perhaps, be accounted for by such a separation of the layers.

Brook gives from twenty to thirty as the number of the oil globules, whereas, I found only from eleven to nineteen in a considerable number which I counted, whilst Raffaele† found only from four to ten in ova of 1.166 mm. which he refers to this species, remarking that the slight discrepancy is probably due to local variation. Brook makes no mention of any colouration of the globules, which are distinctly yellowish (as in Raffaele's) or yellowish-green (fig. 31) in my specimens, both early and advanced. I noticed one exception in which, at a very early stage, the globules were colourless, but acquired an unusually pale yellowish tint as development proceeded. As regards development, I have little to add to Brook's excellent account.

Pigment of a pale yellow colour (black by transmitted light) appears in minute round chromatophores in the embryo before the outgrowth of a free caudal region, and spreads outwards from the sides over the yolk sac, the whole of which is eventually studded with it (as in fig. 32). When the embryo possesses a free caudal region equal to the rest of its length, the yellow chromatophores have become larger and stellate, with a brilliant orange hue (brown by transmitted light); they extend dorsally and ventrally along the free caudal region almost to its posterior extremity, and along the gut on either side. Small black chromatophores (fig. 32) have also appeared, following the course of the yellow pigment in the postanal region, and distributed sparingly and somewhat irregularly over the anterior part of the body. Stellate black chromatophores, much less abundant than the yellow, occur on the yolk sac. Thus, at a comparatively late stage of development in ovo, the yellow pigment is altogether in excess of the black, a condition which is reversed in the older stages. The black chromatophores of the trunk become stellate and increase greatly in size; they appear on the brain, about the eye and the large otocysts, on the base of the pectorals, and on the pelvic fins, whilst the yellow pigmentation of the trunk appears to diminish.

In the recently extruded larva (fig. 37), still mouthless and with comparatively large yolk (y), the black pigment of the trunk forms a conspicuous line, dorsally and ventrally, from the pelvic fins to the commencement of the posterior fourth of

the notochordal region, thus differing from the condition shown in Brook’s newly-hatched larva (op. cit., pl. 6, fig. 27). Thereafter the black pigment of this region tends to become concentrated into two bars—one midway along the post-anal region, and the other above the anus, sending dendritic lines on to the dorsal fin, which apparently mark the site of the future first permanent dorsal fin (fig. 38, d. i.). This is the condition when the postlarval condition is reached (fig. 38) when all yellow pigment has disappeared, except three patches along the margin of the embryonic-dorsal fin. The eyes are black, and the roof of the abdomen and the rectum are profusely pigmented. There is, thus, at this stage, no practical difference from the condition shown in Brook’s figure of an embryo of three days (op. cit., pl. 6, fig. 29).

The most interesting condition in this form is the development of the paired fins. At a comparatively early stage (fig. 15) what appears to be a fold of epiblast is pushed out from the lateral region of the embryo, occupying about the middle-third of the pre-anal length, and never, as far as can be seen, extending back to the region of the embryonic-ventral fin. The anterior and posterior portions of this fold develop rapidly, forming a couple of slight prominences connected by a narrow ridge (e. r.). The prominences represent the pectoral (p. f.) and pelvic (pl. f.) fins, which thus, at their earliest stage, are connected by a continuous epiblastic ridge, which may even be regarded, as Balfour suggests in Elasmobranchs, as a continuous lateral fin.

Though at first equal,† the pectoral soon outstrips the pelvic fin in development, and the connecting ridge disappears or becomes very inconspicuous. At hatching (fig. 37) the pelvic (pl. f.) still retains its original position behind the pectoral (p. f.), the bases of the two being in the same straight line. As the yolk is absorbed, the pectoral undergoes the usual rotation, and is carried downwards and forwards to the clavicular region (fig. 38, p. f.), whilst the pelvic (pl. f.), now growing more rapidly, is similarly rotated, and travels downwards and forwards to a ventral position a little behind the pectoral; the assumption of the jugular position is a feature of later development.

From Brook’s account (“L. S. Journal,” vol. xviii., p. 298) it appears that the pelvic fins appear very early in Motella mustela, though this was not noticed by M’Intosh and Prince (op. cit.) in the same species, nor by Raffaele (op. cit.) in Motella tricirrata.

Pelvic fins do not appear till much later in all other Teleostean with pelagic ova, of which the development has been studied.

* “Comparative Embryology,” vol. ii., p. 611.
† Brook speaks of the pelvic fins as appearing later than the pectoral, but both fins seemed to me to be developed at the same time.
The newly-hatched larva (fig. 37) measures 3.27 mm. in total length, the pre-anal length being 1.49 mm. The marginal fins are of moderate size; the dorsal commences on the mid-brain; the caudal is spatulate, with embryonic fin rays, and there is a very minute pre-anal fin (pa. f.). The notochord is multicolumnar. The oil-globules (o. g.) lie principally along the ventral surface of the yolk. There is no mouth, and the anus (a.) is imperforate. A small urocyst (u.) is present.

When the postlarval stage is reached (fig. 38) (about three days after hatching) the total length is 3.51 mm., the increase being in the post-anal region. The marginal fins are broader; the dorsal extends to the snout. The mouth is open, with well-developed jaw and branchial apparatus, and the anus is perforate.

Raffaele notes that the ova of this species are shed in spring, and take about eight days to hatch, the last three or four days being spent at the bottom. Brook ("Spawning Period of British Food Fishes," loc. cit.) gives April, May, and early June as the spawning period on the Yorkshire coast, and June and July in his Aquarium. Day gives spring. A single egg has been obtained this year at St. Andrew's in the latter part of July.

Cottidæ.

**Trigla gurnardus.** Grey Gurnard.

The well-known ova of this species* occurred frequently in the tow-nets, and many ripe as well as spent females occurred in the trawl. Possibly some of the ova attributed to *T. gurnardus* may have belonged to *T. cuculus*, as Cunningham (op. cit.) has shown that the ova of these two species are identical in dimensions, whilst his descriptions of the later development of the latter species afford no distinctive character. The length of the larva is the same in both, and the great size of the rudiment of the pectoral fin, which he describes as the most peculiar feature of the larva, is equally well marked in *T. gurnardus*.

*Trigla hirundo*, the sapphirine gurnard, is another species which appears to spawn about June and July, and probably later, as we obtained several males with enormously developed testes, which gave them the appearance of pregnant females. No females were obtained. Couch gives from January to June as the spawning period of this species.

Gobiidæ.

Gobius niger (Linn.) (?) The Black Goby.

(Pl. xlvii., fig. 12.)

A post-larval goby, 11 mm. long, occurred in the bottom net in Blacksod Bay on the 14th June.

From the nature of the pigment, I am inclined to refer it to this species. The young of G. minutas and G. ruthensparri have been long known at St. Andrews, though they cannot as yet be with certainty distinguished in their earlier stages. Their pigmentation is, however, uniformly pale, differing markedly from what is seen in this specimen. The jaw apparatus is fully developed, but no teeth are visible. The head is large, with slightly upturned snout; the lower projects beyond the upper jaw. A large translucent opercular flap (op.) is present; the gill arches are serrated. The large otocyst has a dorsal prominence, and shows considerable resemblance to that of the larval Gobius, figured by me in Ann. and Mag. Nat. Hist.† The clavicle (cl.) is conspicuous: its inferior half is forwardly directed, and is overlapped by the opercular flap (op.). The pectorals are very large and fan-shaped, and the fin-rays are conspicuous, as in the early larva.

The abdomen is contracted, and tapers off from the middle of its length to the anus (a.), which is somewhat posterior to median. The air-bladder (a. b.) is very conspicuous as a large ovoidal sac, lying in the sub-notochordal region at the top of the abdomen. The marginal fins still persist, but the fin-rays of the permanent second dorsal (d. l.) and ventral (p. v. f.) fins are seen. There is no sign as yet of the first dorsal; but this fin, judging from the young of other species, is very late in making its appearance in fishes of this genus. The notochord is still visible, but the abundance of pigment renders its structure obscure. The extreme posterior end of the caudal region is slightly turned up, and there is a deeply pigmented pyriform hypural lobe (hp.) from which, as from the upturned notochordal region, embryonic fin-rays extend into the spatulate caudal fin. There is a considerable pre-anal fin (p. a. f.). The eyes are black, with dark-greenish lights. The surface of the head and body is covered with a dull olive-green pigmentation, which is only absent from the pectoral and marginal fins, opercular flap, and the tips of the jaws. This green colour is somewhat darker on the top of the head and abdomen than elsewhere, and small black chromatophores are distributed pretty thickly over it, except in the upturned caudal region. In addition to this, four bands of reddish-brown stellate chromatophores cross the body at various points. The first descends obliquely from the dorsum, passing just behind the air-bladder to the ventral edge. The second crosses vertically at

the level of the anus, and is widest dorsally and ventrally. The third band is not very conspicuous; it lies at the commencement of the 2nd third of the post-anal region of the trunk.

The fourth and last band is the most conspicuous and broadest, embracing the hypural thickening, and the trunk for some distance in front of this.

From the abundance of the pigment, the body has little translucence. The reddish-brown, conspicuous by transmitted light, is not distinguishable by reflected light from the surrounding black pigment.

The general effect to the naked eye is a dark olive-green, crossed by black bands at the regions described.

Compared with the figure of the larval goby, the anus in this specimen is seen to be much further back, occupying indeed a position posterior to that seen in the adult. Such a condition occurs also in late post-larval and young specimens of *Gobius ruthensparri* and *G. minitus*.

The ova of *Gobius niger* are figured in the note previously referred to.*

**Callionymus lyra** (Linn.). The Dragonet, &c.

(Pl. li., figs. 40-42.)

A few ova of this species were taken in the surface net off Cleggan Head on the 12th June, in Inver Bay on the 20th June, and in Blacksod Bay on the 10th July.

The eggs are well known, but the larva has hitherto escaped attention. I was successful in hatching two eggs on this occasion.

The newly-hatched larva (figs. 40 and 41) has a total length of 2·08 mm., of which the head and yolk (*y.*) occupy 895 mm. The snout is as yet blunt, and the head has the rounded contour usual in early larvae from pelagic ova. The eyes are comparatively large at this stage, with a conspicuous choroidal fissure. The otocysts (*ot.*) are small and oval, and as yet remote from the eyes. The cerebellar fold is rather large, but the pineal sac is not as yet visible. The heart (*h.*) is lodged in a depression of the yolk (*y.*), which is still very large, 35 mm. by 505 mm. The yolk sac (*y. s.*) is rather thick, and exhibits certain irregular nodosities in optical section (cf. fig. 40). Faint striae are visible on the surface of the yolk, which has a slight median lateral constriction. The body has somewhat of an S flexure (fig. 41), being incurved over the yolk, and upturned midway between the latter and the posterior extremity. The gut is small, but is tubular for part of

* In this note, while referring to Hoffmann's work on the subject, I overlooked a figure (Taf. iii., fig. 9) described as the egg of *G. minitus*. I cannot regard Hoffmann's identification as correct, since he shows the attachment process as a ring of simple filaments, very different from the reticulate condition of that structure which I have observed in the ovarian eggs of *G. minitus*. 

---

**Holt—On the Eggs and Larvae of Teleostei.**
HOLT—On the Eggs and Larvae of Teleosts.

443

its length. Its thickened region fails to reach the hinder end of the yolk, and terminates in a conical process, from which the narrow cord-like rectum (r.) passes down along the posterior of the yolk sac to the marginal imperfect annus (a.).

The marginal fins (fig. 41) are of moderate size, and about equal in height with the free caudal region of the trunk. The dorsal commences behind the otocysts (ot.), the caudal is short and rounded, and the ventral sends forward a narrow strip along the postero-ventral border of the yolk sac (v. s.).

The notochord (n.) is unicolumnar throughout; the cells do not show the same ampullation as in the herring, &c. The pectorals have not appeared. The pigment is a bright orange, dark by transmitted light. It occurs in a conspicuous patch on the snout. There is a well-marked bar (p. b.) extending into the dorsal fin, across the middle of the free caudal region of the trunk, an arrangement common to many larval fishes. In front of this, two lines of round chromatophores, dorsal and ventral, run forward along the sides to the cephalic region, the dorsal line extending on the top of the midbrain. Similar chromatophores are scattered over the posterior moiety of the yolk sac, and a few occur on the edge of the ventral fin near its commencement.

Two large pigment patches occur on the edge of the anterior half of the dorsal fin, and there are a number of small chromatophores along the bases of the dorsal and ventral fins about the posterior extremity of the body.*

The newly-hatched larva, whilst presenting resemblances to that of C. festivus (see Raffaele, op. cit., p. 33) in the character of the pigment and the large size of the yolk, differs from that form in the possession of a well-developed heart at the time of extrusion.

Raffaele says nothing definite as to the dimensions of the larva ("piccola"), nor does he allude to the structure of the notochord in the Mediterranean species. From his figure of the newly-hatched larva, it is evident that the rectum is even at that stage separated from the yolk.

I cannot say anything as to the time the egg of C. lyra takes to develop. In the specimens described above the embryo was considerably advanced when taken on the evening of the 20th June, and hatched on the following day. The faint striae noticed on the yolk surface in the larva may have some relationship to the vesicular layer of the yolk of C. festivus, though it is remarkable that, if any trace of such a structure exists in C. lyra, neither McIntosh† and Prince or Cunningham should have detected it in the ova. I certainly saw nothing of the sort in any of the ova that came under my notice.

* Whilst under observation minute tubercles made their appearance all over the integument of this specimen (as shown in figure 41). Death ensued shortly afterwards.

† The ovum of this species was first described by Professor McIntosh in the Ann. and Mag. Nat. Hist. Dec. 1885.
Another egg of this species, which on the 30th June contained an advanced and pigmented larva, was found twenty-four hours later to have hatched. The larva (fig. 42) is probably now at least twelve hours old, and shows a considerable advance on the newly-hatched condition. The total length is 2·20 mm., having increased by 1·12 mm. The yolk is much reduced, and has now an elongated ovoidal shape, narrowest in front. The fore brain has undergone a certain upward rotation and the pineal (pn.) is visible as a distinct prominence in profile. No mouth is as yet present, but the development of a pre-nasal rostrum has increased the acuteness of the frontal angle, imparting to the head something of the shovel-like contour familiar in the adult. The hind brain is shortened, bringing the otocysts (ot.) nearer to the eye. There is as yet no appearance of the enormous development of the brain met with in older stages,* and the eye is still comparatively large. The pectorals (p.f.) have appeared as small semicircular flaps in rear of the otocysts. Beneath them the gut shows a dilatation. The posterior region of the gut now extends some way behind the yolk under the notochord, the cord-like rectum (r.) descending to the marginal imperforate anus (a.) at a short distance behind the yolk (y.), a condition due to the shortening up, by absorption, of the latter. The post-anal region measures 1·18 mm., the anus being slightly anterior to median.

The marginal fins have undergone considerable expansion, especially the dorsal, which now commences at the snout, passing up over the fore- and mid-brain as a narrow fold, and thence increasing till it reaches its greatest height above the posterior extremity of the yolk. The embryonic caudal fin is not affected by this expansion, but embryonic fin rays have appeared in it (fig. 42).

The arrangement of the pigment has undergone certain changes. The chromatophores over the posterior two-thirds of the yolk sac have become stellate. Pigment has appeared round the inner edge of the iris. The body pigment is now restricted to the neighbourhood of the otocysts, the post-anal band (p.b.), which is more conspicuous, and the caudal extremity, where the chromatophores are now aggregated into a dorsal and ventral patch. The two lateral lines of chromatophores in the anterior region have disappeared, or have in part migrated to the posterior extremity of the tubular part of the gut, and the narrow rectal region. One chromatophore occurs on the pectoral fin.

The two marginal patches of the dorsal fin have increased in size, but have migrated backwards, and now occupy the extremities of the central third of the expanded portion of the fin (i.e. the part between the mid-brain and caudal fin). A large marginal patch has appeared on the ventral fin below the post-anal bar, and small chromatophores occur along the edge of the fin from this point to the

* Cf. McIntosh and Prince, op. cit., p. 864.
yolk. None of the darker pigment characteristic of the older forms has as yet appeared.

No striations of the yolk are visible in this specimen. Compared with Raffaele's figure of a larval *C. festivus* on the second day after hatching, it is seen that the marginal pigment patches of the dorsal and ventral fins are characteristic of both forms. In the Mediterranean species the development of the brain, and in our own that of the snout, seems the more precocious, the exaggeration of both structures being characteristic of the older forms of *C. lyra*.

It may be permissible here to advert shortly to the question of the affinities of this form. Raffaele remarks that in development and early conditions it has nothing in common with the Gobies, amongst which it is classed. The hexagonal marking of the zona (vitelline membrane), so conspicuous in *C. lyra* (but absent in *C. festivus*), was found by Raffaele also in the fertilized egg of *Uranoscopus seaber*, and in the ovarian egg of *Saurus lacerta* (op. cit.). Putting aside *Saurus*, Cunningham (op. cit., p. 37) regards the occurrence of this common feature in *Callionymus* and *Uranoscopus* as suggesting "some interesting possibilities with regard to the true systematic affinities of these two genera," the latter of which is classed with the Trachinidæ. He alludes to certain peculiarities of adult structure common to the two forms, and points out that whereas the Trachinidæ are mostly laterally compressed, *Uranoscopus* is depressed from above downwards, and has the two eyes directed upwards and placed on the flat upper surface of the head. This, it may be remarked, is equally true of *Gobius minutus*.

Cunningham concludes that it is probable that "Callionymus and *Uranoscopus* are closely allied, and that either the Callionymina ought to be included among the Trachinidæ instead of among the Gobiidæ, or that the Callionymina and Uranosecpina form a single family distinct both from the Gobies and the Weevers." The fact that the eggs of the typical gobies are adhesive whilst those of Callionymus are pelagic appears to me of no great weight, as both pelagic and demersal eggs occur in the Labridæ, and even in the single genus *Clupea*; and such goby-eggs as are known to us, so far from being typical, are as aberrant in their own way as those of Callionymus. That the presence of oil-globules in the ova of Trachinus and their absence in those of *Uranoscopus* can be regarded as seriously lessening the chance of affinity between these two forms appears improbable, as oil-globules are present or absent in the ova of different species of the same family, such as the Labridæ and Gadidæ, and even in the same genus (e.g. *Clupea*). The occurrence of the hexagonal marking in *Saurus* would seem to indicate that no great importance can be attached to this structure. *Saurus* is one of the Scopelidæ, a Physostomous family having certainly no close relationships to either of the other forms.

As to the relationships of *Callionymus* to the gobies it may be pointed out that the unicolumnar condition of the notochord, by no means a common feature,
occurs in both Gobius and Callionymus, though too much stress should not be laid on a feature which appears in widely separated groups, and is variable within the limits of a single genus.*

In Callionymus and Gobius, the notochord cells (vacuoles) are smaller and less inflated than those of the herring, which Kupffer (Entwickelung des Herings im Ei. Jahresb. Comm. deutschen Meere. 1874–76: Berlin, 1878) has shown to arise from more numerous and smaller roundish polygonal cells. Of the origin of those in the dragonet and goby we have at present no knowledge.

Cepolidæ.

Cepola rubescens (Linn.). The Red Riband Fish.

(Pl. xlvii., fig. 22.)

A female of this species, 11½ inches long, occurred in the stomach of a large grey skate in Inver Bay, on the 25th of June. It was somewhat macerated, and the ripe ovaries, with other viscera, were exposed. A number of ripe ova were scattered about in the skate's stomach. The ovum (fig. 22) is translucent, with a thin minutely-pitted zona. The diameter is 72 mm. The yolk (y.) is homogeneous, translucent, and colourless, except at the periphery, which exhibits a brownish opacity in optical section. It is somewhat collapsed, a condition which, with the brownish tinge, is doubtless due to the action of the gastric juices. The zona shows no sign of collapse, and appears perfectly spherical. There is a single large oil-globule, 1·35 mm. in diameter, with a somewhat smoky margin, like that of Trigla gurnardus.

From its small size, thinness of zona, and character of yolk, I am inclined to regard this as a pelagic egg. My specimens were, of course, of no service in demonstrating the buoyancy (or otherwise) of the living egg.

This species is abundant in the Mediterranean, but the ova, if pelagic, have escaped Raffaele's attention.

Gobiesocidae.

Lepadogaster bimaculatus (Donov.). The Doubly-spotted Sucker.

(Pl. xlvii., figs. 1-7.)

On the 12th June a whelk-shell was obtained in the trawl in Clifden Bay, and proved to contain a specimen of *Lepadogaster bimaculatus*. On breaking the mouth of the shell a number of ova were revealed, attached to the inside of the last whorl near its commencement.

The shape of the ova (figs. 1-3) is remarkable. They are not globular, as described by Hyndman,* but ovoidal and abruptly truncated inferiorly (fig. 1), having something of the shape of an ordinary dishcover. The length is 1·37 mm., the breadth 1·08, and the height 1·68 mm., but these dimensions, as also the contour, are subject to slight variations. There is a single, large, colourless oil-globule (o.g.) of 24 mm. M'Intosh and Prince (op. cit., p. 672) noted that the zona shows very evident punctures.

The flattened under-surface of the egg (fig. 4) adheres to the shell by means of a remarkable attachment apparatus. The micropyle is central, and is closed in the somewhat advanced stages studied. Its site is visible from below as a minute clear, oval area (mi.), from the edges of which numerous interlacing fibrils radiate outwards, forming by the cohesion of their distal ends a structure resembling a shallow circular basket with a thickened rim (r.p.), from which are given off very numerous fine filaments (fil.) of considerable length. It is evident that these filaments have an adhesive function in the freshly-extended ovum. In favourable preparations it is seen that this plate-like structure is continuous with the rest of the zona only in its centre, i.e. around the micropyle (mi.). In addition to this central apparatus the whole of the flattened surface of the zona is studded by numerous short, stout, rod-like bodies (rd.), having rounded bases springing from the zona, whilst their distal extremities, which are directed towards the periphery, bifurcate, and thereafter taper very rapidly into long and extremely fine adhesive filaments (fil., fig. 4) similar to those of the central structure. These can be seen, in an isolated egg viewed from above (fig. 3), projecting as a fringe (fil.) beyond the edges of the inferior surface. The zona is of moderate thickness, and there appears to be no layer external to it. Treated with picro-carmine it takes on the carmine stain faintly, whilst the attachment apparatus is entirely unaffected by it, with the exception of the thickened rim (fig. 4, r.p.) of the central structure. This

* This observer gives about ¼ inch as the diameter. Day, "British Fishes," vol. i., p. 193.
is somewhat remarkable, as the attachment process in the egg of Gobius* takes the
carmine stain very deeply and readily.

The yolk (y) is colourless and translucent, and very finely granular. The
oil-globule (o. g.) appears to occupy a variable position, as in some other demersal
ova; the embryos in different ova at the same time present such differences in
development as to induce the belief that the parent deposits them in batches from
time to time. Judging from Mr. W. Anderson Smith's account (Notes on the
1886, pt. i., p. 145) the eggs of L. decandolii are all deposited at the same time, as is
the case with most demersal ova. In some of the ova before us the embryo at the
time of capture had a long, free, caudal growth, others had no free caudal growth,
and only four protovertebrae (fig. 3), whilst intermediate stages occur. In the
least advanced stages a large Kupffer's vesicle (k. v.) was present. The embryo
occupies a horizontal position in the egg, the yolk (y) being laterally compressed.
Mr. Anderson Smith notices great irregularity in position in the embryo in the
eggs of Lepadogaster, but in my specimens the horizontal position appeared
constant. I did not experience the difficulty met with by that observer in
isolating the ova of this species; on the contrary these appeared much easier to
isolate than such demersal ova as those of Centronotus, which adhere to each other,
and possess no attachment processes.

The larva, on emerging (figs. 6 and 7), has a total length of 2·97 mm.,† of
which the pre-anal region occupies 2·08 mm. The yolk (y. and fig. 5) is small,
transversely elongated, and somewhat bilobed. Anderson Smith noticed that it is
smaller than in L. decandolii. The head is large, and the parts of the brain are easily
made out, the medulla (m. o.) rising to a conspicuous hump behind the cerebellum.
The eye is large, with a comparatively large pupil. The otocysts are large and
near the eyes. The top of the head and back are very much flattened, a condition
well shown in a dorsal view of the larva (fig. 7). The pectorals (p.f.) are stout
and fan-shaped. The gut, which extends far back, is very large; the anus (a.) is
perforate. The mouth (m.) is subterminal, and the turning up of the mandibular
symphysis below, and short of, the anterior extremity of the upper jaw imparts a
characteristic appearance to the head. The marginal fins are narrow; the embry-
onic caudal somewhat lanceolate, and a very narrow pre-anal fin (p. a.f.) extends
from the yolk to the anus. The only pigment I could detect is black, and takes
the form of small round chromatophores. These occur on the lower jaw, along
the ventral region of the yolk sac on the pectoral fin, dorsally and ventrally on
the gut, and in four ill-defined rows along the sides of the body, except at the

† Some as long as 3·15 mm., and advanced in pigmentation.
extreme posterior end. Of these four rows the most dorsal marks the boundary of the flattened dorsal region, and extends forward on to the mid-brain (m. b.); whilst posteriorly several chromatophores occur between the two rows. Post-anally the ventral rows unite to form a single line along the ventral edge of this region.

The pigmentation of the eyes is variable: in some larvæ there are only a few chromatophores on the iris, which is perfectly black in others.

There is considerable resemblance to Mr. Anderson Smith’s figure of the larva of L. decandoli. The gut appears to extend further back in our species. Mr. Anderson Smith also figures ova of L. decandoli, from which it appears that they are nearly circular, and contain a single large oil-globule. He mentions that they have a pinkish tinge, which distinguishes them from those of L. bimaculatus, but he gives no dimensions of the eggs or larvæ of either species, and does not allude specially to the shape nor to the method of attachment of the eggs. He points out that both species spawn in June and July, and that the ova are hatched in twenty-eight days. Those of L. bimaculatus, according to the same authority, are almost always arranged in regular layers (a condition which I did not notice in my specimens), within the empty shells of Pecten opercularis. Day, on the authority of Mr. Hyndman, records them from the shells of Venus virginea and Pectunculus pilosus.

Labridæ.

Labrus maculatus (Bl.)* The Ballan Wrasse. The Gunner (Mayo Coast.)

Raffaele (op. cit., p. 35), observes that the ova of Labrus (L. merula, &c.), and Crenilabrus (C. griseus, C. mediterranius, and C. pavo) are demersal, the former being adherent, and the latter non-adherent.

Day (op. cit., vol. i., p. 253) gives the breeding season of L. maculatus on the Galway coast as about June, and quotes Moreau to the effect that this species and L. mixtus form nests for the reception of their spawn.

Day’s observations on the breeding season are to some extent confirmed by our own experience. We obtained specimens only on one occasion, the 8th July, at Inishkeagh.

They were all spent, males and females alike; but several of the females appeared to have spawned recently, judging from the condition of the few ova which, as usual, were retained in the ovaries. They are spherical, and the diameter is from 1·01 to 1·07 mm., in some instances reaching 1·13 mm.

In most the egg contents are reduced to an opaque ochreish granular mass, occupying the centre of the egg, whilst in a few of the larger ones the yolk has a diameter of 1·01 mm., and is colourless and translucent, except for an irregular

* See note on p. 473.
central opacity. In some the yolk fills the entire available space, as in fresh ripe ova before fertilization. The zona is somewhat thick, and minutely punctured. No external membrane or attachment process can be made out, and it is to be supposed that the ova, if adherent, as in the Mediterranean species of this genus, are so in virtue of a viscous oviducal secretion, as in Cottus, Cyclopterus, &c. The yolk is extremely resistant in spirit preparations, and appears to possess a thin outer membrane (periblast), having a dotted surface presumably corresponding to the punctures of the zona.

_Crenilabrus melops_ (Linn.). The Cork-wing Wrasse, &c.

On the 12th June I obtained some apparently ripe ova from females of this species in Clifden Bay. They were colourless and translucent, and the yolk appeared perfectly clear. No oil-globule was present. Unfortunately my measurements of these ova have been mislaid.

On the 7th July I again obtained some females in Blacksod Bay. In one of them the ova appeared about three-quarters ripe; they were opaque and ochreish yellow, ovoidal in shape, having a long and short diameter of 10 mm. and 8 mm. respectively. The other females were either spent or immature.

It is noticeable that this species comes to maturity at a very small size. Of a number that I examined, both male and female, every specimen exceeding 4 inches in size had well-developed reproductive organs, either approaching maturity or recently spent. A male of 10 inches, the largest obtained, had partly spent testes.

From the spent females I obtained a few eggs that had been retained in the ovaries, as happens frequently in Teleostean.

They are spherical, with a diameter of 17 mm. The yolk is colourless, but has a milky-white opacity, probably due to incipient decomposition.

The zona is, as usual, covered with minute punctures. There is no attachment process, and optical sections do not show the division of the egg-capule into two layers, such as Hoffmann (Zur Ontogenie der Knackenfische, p. 18, Verhand. Konink. Akad. v. Wetenschappen, 1881) found in _C. pavo_. According to this observer, the egg of the latter has a diameter of 75–78 mm., while the newly-hatched larva is 3·6 mm. long. List (Zur Entwicklungsgeschichte der Knackenfische, I. Labriden; Zeit. f. wiss. Zool., vol. xlv., 1887, pp. 595–645) examined the ova of five species of this genus from the Adriatic, and gives an excellent account, with figures, of the development in _ovo_ of _C. tinea_ and _C. pavo_. He gives 9 mm. as the diameter of the egg of the former, remarking that that of the latter is somewhat larger, thus disagreeing with Hoffmann's measurements. The yolk appears to be yellowish in both species. At hatching the larva of _C. tinea_ is
2·5 mm. long, that of C. pavo being longer and more advanced. In both the mouth is unformed, the notochord is multicolumnar, and the anus posterior to median, with a considerable embryonic pre-anal fin. In addition to yellow pigment, there are very large stellate chromatophores of bright blue, a colour not usually met with in body pigment of teleostean larvae. There is no pigment on the marginal fins.

List further observes that the zona is divisible into two layers—the outer consisting of regular hexagonal prisms, whilst the inner is faintly stratified. M’Intosh and Prince (op. cit., p. 673) show that the zona of Liparis montagui exhibits similar hexagonal markings, but do not record an inner layer. The condition recalls that of Callionymus and other forms.

GADIDÆ.

Merluccius vulgaris (Cuv.). The Hake.

A female with nearly ripe ova occurred in the trawl in Inver Bay, on the 25th June.

A few translucent and apparently ripe ova were obtained; they were not quite spherical, having a long diameter of 1·35 mm. and a short diameter of 1·08 mm., with a single large oil-globule of 0·30 mm.

Raffaele (op. cit., p. 37) gives 0·94—1·03 mm. with oil-globule 0·27 mm. as the dimensions of the ova of this species, which he describes as spherical.

The spheroidal condition of my ova was perhaps abnormal, as they were not perfectly fresh when measured, but they were certainly larger than in the Mediterranean form.

According to Raffaele this species spawns at the end of January in the Mediterranean. Brook gives March to May, and June to September as the spawning period on the west and east coasts of Scotland, respectively, quoting Couch to the effect that the period on the Cornish coast is August.

The large size of the oil-globule renders this a very conspicuous egg, which should be easily recognized if obtained in the tow-nets.

MACRURIDÆ.

Macrurus, species?

Amongst the contents of the trawl from 450 fathoms off Achill Island, on the 10th July, were two large females, of a species not yet identified,* with enlarged ovaries.

* Since identified as M. rupestris.
The eggs, which appear about three-quarters ripe, or less, are spherical, opaque, and whitish. The diameter in the largest is from 1·25–1·31 mm. There is as yet no appearance of a single oil-globule, though oleaginous matter is, as usual, abundant in the egg contents. The zona, surrounded by the granulosa, is thick and multi-laminate, with very conspicuous radial pores, terminating in minute surface punctures. There is no trace of the mosaic of concave hexagonal facets described and figured by Raffaele (op. cit., p. 65) in his species No. 4, attributed to this family, nor does an optical section show the tubercles found by Costa on the ovarian egg of *M. caelorhynchus*. My specimens, however, had still a considerable period of intra-ovarian life before them.

**Pleuronectidæ.**

*Rhombus laevis* (Rondel). The Brill or Brit.

(Pl. xlviii., figs. 13 and 14.)

A female was obtained in Blacksod Bay on the 16th June, and proved to contain ripe ova: I could not fertilize them, as no ripe male occurred on the same occasion.

The ripe unfertilized egg (fig. 13) floats buoyantly, and has a diameter varying from 1·25 mm. to 1·37 mm., with a single pale oil-globule (*o.g.*) of 21 mm., which in some cases shows a faint, dull-yellowish colouration round the edge. The yolk is colourless, clear, and homogeneous. The punctures of the zona are very evident, and the radial pores are very conspicuous in optical section; the zona has the appearance of being very much wrinkled, as is the case in some ova before fertilization. Examination of flattened ova under a high power shows that whilst the external surface is smooth, the zona is not of uniform thickness throughout, the internal surface being raised into ridges, similar to, but more pronounced and numerous than, those in the unfertilized ova of *Pleuronectes cyanoglossus*. This may be due to artificial causes. This observation may, I think, be taken as confirming Raffaele's surmise (op. cit., p. 48) that certain pelagic ova (having a diameter of 1·32 mm., with an oil-globule of 21 mm.), taken by him at Naples in the summer, belonged to this species. The differences of measurement are insignificant. M'Intosh and Prince (op. cit., p. 847) obtained similar ova at St. Andrews in February and March, so that the spawning season of this form appears to extend over a considerable period in the British Isles.*

A single egg (fig. 14) apparently belonging to this species, with diameter 1·31, and oil-globule 21 mm., occurred in the surface-net in Clew Bay on the 2nd July.

The zona in this specimen exhibits nothing of special interest; the perivitelline space is small; the embryo is little advanced, with about four protovertebræ: no pigment is present; the oil-globule has migrated a short distance towards the posterior region.

Pleuronectes microcephalus (Donov.). The Lemon Dab, or Lemon Sole.

Pl. xlviii., figs. 19–21; Pl. l., fig. 39.

Ripe females were obtained frequently, yielding an abundance of mature ova. Some which I measured on the 25th June had a diameter of 1·25 mm.,* being thus smaller than those measured by Mr. Cunningham, at Plymouth† (op. cit., p. 15). I endeavoured to fertilize these, but without success. Four hours later they were still translucent and floated buoyantly, whilst in a few a small perivitelline space had appeared, as after fertilization.

Cunningham (ibid.) points out that "the external surface of the vitelline membrane shows a number of fine raised ridges forming two systems of parallel lines which cross one another diagonally." M'Intosh and Prince give a figure (op. cit., Pl. l., fig. 18) of part of the zona under a high power, showing a somewhat irregular reticulation of lines, seen as white spaces on the closely dotted surface. The latter condition is more in accordance with my own observations. Examination of the zona in the living egg (fig. 21) certainly gives the impression described by Cunningham, but if it is ruptured and flattened out, it is seen (fig. 20) that the markings are extremely irregular. There are certainly two general systems of parallel lines, but these lines are by no means continuous, frequently ending blindly, converging and diverging, or bending abruptly to continue their course at a different level. Seen from above the markings appear as a line on to which the thickly-set punctures of the rest of the zona do not extend. By tracing the lines to a point where the zona is doubled over so as to present an optical section, it is clearly seen that they are not ridges at all, but sharp grooves indenting the surface of the zona from about a quarter to a half of its thickness, according to the size of the lines, which are of varying widths. In some instances the sides of the grooves are very slightly raised above the general surface level.

By the kindness of Professor M'Intosh I have been enabled to add to my

* Some dead fertilized ova of this species in the tanks here measured from 1·2 to 1·31 mm.
† Mr. Cunningham gives 1·36 to 1·44 mm., "though individual ova may be a little smaller or a little larger." In an earlier paper he gives 1·1 mm. as the diameter of the mature (unfertilized) ovum.
observations from some ova of this species which he is at present developing. I cannot find these markings in ruptured zonae, from which the larva has escaped, and they are very faint in dead and decomposing ova.

Only a single egg (fig. 19) of this species, with a diameter of 1.25 mm., and showing the peculiar marking of the zona, occurred in the tow-nets, viz. in the surface-net, in Inver Bay, on June 25th.

It is at a stage somewhat in advance of that shown by Cunningham in his figure 7 (op. cit.), having a free caudal region about equal to the rest of the body, and a broad marginal fin. Pigment is altogether absent, though black chromatophores are shown by Cunningham in the figure alluded to, having first appeared on the previous day.

Professor M'Intosh pointed out to me long ago that a temperature slightly higher than normal frequently brings about a precocity of pigment, a phenomenon very noticeable in the development of the sprat. This probably accounts for the difference in the condition of pigmentation in Cunningham's ova and my own, though the latter, a single specimen, may perhaps be abnormal. Three days later I found that the larva had escaped, and was darting actively about the vessel, occasionally resting for a time at the surface.

It is now (fig. 39) apparently at a stage between those shown by Mr. Cunningham in figures 8 and 9, and does not altogether agree with his descriptions. The length is 3.98 mm., a little longer than Mr. Cunningham's newly escaped larva. The snout projects boldly, but the mouth is as yet unformed, though the branchial bars are visible. The mid-brain (m.b.) is rather prominent dorsally, its greatest height being behind, instead of in front of, the middle of the eye, as in Cunningham's figure 9. The nasal sacs (p.f.) are apparent just in front of the eyes, which to some extent overlap them. The otocysts, which are omitted in Cunningham's figure 8, are large, of the usual shape, but somewhat upwardly rotated on the hinder ends, and lie a little distance behind the eye. The pectorals (p.f.) are considerably developed, they have undergone a partial rotation, and are somewhat in advance of the position at which these organs usually make their first appearance.

The gut is large and tubular. It displays two dilatations close behind the pectoral fins, representing the liver and stomach. The intestinal region of the gut is very ample, and there is a sharp constriction immediately in front of the rectal region (r.), which ends blindly short of the margin of the ventral fin, appearing in this respect to be somewhat abnormal. The anus is as yet imperforate, and there is no appearance of an urocyst. The yolk (y.) is narrow and elongated, and the space in front of it, spoken of by Cunningham as the venous sinus, is much smaller than in either of his figures. The posterior end of the heart (h.) is against the front wall of the yolk. The marginal fins are rather narrow, the dorsal com-
Holt—On the Eggs and Larvae of Teleosteans.

\[455\]

... effects just behind the level of the otocyst; the caudal is short and narrow, and almost lanceolate. Pigment is of two kinds, black and grass-green (chrome-yellow by transmitted light). The yellow is generally distributed over the head and the anterior and postero-ventral parts of the yolk-sac. From the otocystic region, dorsal, renal, and ventral-intestinal lines of chromatophores run back to the anal region. The post-anal region is crossed by three pigment bands (p. b.), the most anterior of which is rather feebly marked. A few large chromatophores occur on the anterior part of the dorsal fin. Black pigment is found in stellate chromatophores on the top of the head and about the otocyst; antero-ventrally on the yolk-sac, and along the ventral edge of the gut. There are dorsal and post-anal ventral rows of black as far back as the end of the second pigment band, the former reappearing above the third and last band.

**Pleuronectes cynoglossus** (Linn.). The Pole Dab, or White Sole.

The ova of this species were first obtained by Mr. J. T. Cunningham in the Clyde, and are described by him in a Paper "On the Eggs and Larvae of Teleosteans" (Trans. R. S. E., pt. 1, vol. xxxiii., p. 101). He gives 1·155 mm. as the diameter after the formation of the perivitelline space.

The trawl brought up some ripe females in Donegal Bay on the 26th June. I found that the diameter in the ripe unfertilized egg varied from 1·07 to 1·13 mm. The yolk is clear and homogeneous, and the zona has an appearance of close longitudinal striation. In stained spirit preparations under a high power the striation can be reduced to numerous short line-like markings, lying close side by side, with overlapping ends. They appear to be due to the fact, shown in optical section, that the internal surface of the zona is raised up into numerous minute ridges. This condition, which is met with also in the unfertilized egg of the brill, may perhaps disappear with the formation of the perivitelline space, or may be due to the action of reagents; the striation, however, is as well marked in fresh as in preserved specimens.

**Clupeidae.**

**Clupea sprattus** (Linn.). The Sprat.

The ova of this species occurred in the surface net in Inver Bay on June 25th, and in Clew Bay on the 30th June.

Numbers of young sprats between 2 and 3 inches long occurred in the stomach of Acanthias on the latter occasion.
Clupea harengus (Linn.). The Herring.

A post-larval herring, 1\(\frac{3}{4}\) inches in length, occurred in the trawl in Birturbuy Bay in the early part of June.

**Syngnathidae.**

Siphonostoma typhle (Linn.). The Broad-nosed Pipe-fish.

This species was found to be very common amongst the Zostera beds in Clew and Blacksod Bays on the 2nd and 6th July. A single specimen was taken in the shrimp trawl in Killybegs Bay on the 23rd June. Many of those taken in the Zostera beds presented an exact imitation of the colour of the Zostera. All the males observed carried either well-advanced ova or young. The latter were of different sizes in different parents, some being so far advanced that they readily quitted the parent in the bucket in which they were placed on capture. Ryder has described the development of an American species (*S. fuscum*) (op. cit., p. 508).

Syngnathus acus (Linn.). The Great Pipe-fish.

Abundant in the same locality as *Siphonostoma typhle*, and agreeing with it in the condition of the eggs and young. This species occurred also at Inishbofin and other places, and was obtained whenever the shrimp trawl was worked on weedy ground. Young specimens were occasionally obtained in the surface-net, amongst floating weeds, in Blacksod Bay.

Nerophis æquoreus (Linn.). Snake Pipe-fish.

Abundant in the Zostera beds, on the same dates as the Siphonostoma. Many of the males carried ova more or less advanced. As in Siphonostoma, the colouration, save for the transverse bars, presents an exact mimicry of the surrounding Zostera. The same condition was noticeable in specimens of *Hippolyte varians*.

Nerophis lumbriciformis (Willugh). Worm Pipe-fish.

Specimens of this species occurred frequently. A few males, taken amongst the rocks in Killeany Bay, Aran Islands, carried advanced ova (3rd June).
Unidentified Pelagic Ova.

Species I.—Solea (?)

(Pl. xlix., fig. 26; Pl. I., figs. 34 and 35.)

A single egg (fig. 26) occurred in the surface-net, in Clew Bay, on the 1st July, 1890. The diameter is 1·38 mm. The embryo is somewhat advanced, but has only a short free caudal growth. The zona presents no characters of special interest, and the perivitelline space (p. s.) is small. The yolk (y.) has a peripheral layer of clear segments or vesicles (e. v.), which appear somewhat smaller and more numerous than those of Solea vulgaris. A number of oil-globules are present about the periphery of the yolk mass. They are divisible into two sorts:—(1) Very minute globules (o. g. 1), arranged in little groups in the immediate vicinity of the embryo, viz. beneath the head and close to the sides of the anterior third of the body, with the exception of one very small group near the posterior extremity. (2) Larger globules of varying sizes (o. g. 2) scattered irregularly over the general yolk surface. The lens is fully formed, but the otocysts are as yet not visible. A few small black chromatophores occur on the head; and bright-yellow chromatophores are profusely scattered all over the embryo, and on the parts of the yolk-sac immediately adjacent to the head and trunk. There is no pigment on the rest of the yolk-sac.

Four days later, on the morning of July 5th, the larva was observed to have emerged. On the afternoon of the same day it presented the following appearance (fig. 34). Total length 4·10 mm., of which 3·0 mm. is occupied by a precephalic expansion (j.) of the marginal fin, to be hereafter described. The post-anal length is 2·10 mm., the anus (a.) being thus slightly anterior to median.

The cephalic contour is remarkable. The mid-brain (m. b.) is relatively enormous, and projects forward in a blunt point, overhanging the downwardly directed fore-brain (j. b.); the cerebral lobes are large and rounded; the pineal sac is scarcely visible, being masked by other structures. The eye is large, and is antero-ventrally directed: its posterior moiety lies behind the hinder end of the optic lobes (m. b.),—a very unusual relationship. The cerebellar fold cannot be distinguished, but the hind-brain (m. b.) is very large and prominent. The elongated inferiorly concave otocyst (ot.) lies close behind the eye. No mouth is visible, but the branchial bars (b. b.) and slits can be distinguished. With the protrusion of the brain, the anterior end of the notochord is carried forward. A large vesicular expansion (j.) of the marginal fin extends forwards over the head, in front of which it projects like a large bladder. By the aid of dorsal (fig. 35) and profile (fig. 34) views its relationships can be pretty well made out. The
greatest width is in front of the mid-brain; and the posterior limit is about the level of the crystalline lens. Ventrally it is dilated below the free part of the mid-brain, the inferior contour running from a point a little above the cerebral lobes to the top of the eye. A short median fold is directed downwards in front of the pineal region. The heart (h.) is large and active. Its hind end rests against the yolk (y.), which is reduced and pyriform, anteriorly blunt, and still exhibits very clearly the ovoidal peripheral segments (c. v.) The smaller oil-globules have disappeared; the larger ones are scattered over the general yolk-surface, principally at the posterior end. A few largish ones at the front of the yolk very probably represent the coalesced smaller globules.

The pectoral fin (p. f.) is fairly large, but as yet simple; it lies on the dorsal wall of the abdomen, with obliquely rotated base, a little behind the level of the front of the yolk mass. The gut is large and perforate except at the anus. It is bent down in the middle of its length, just in front of which point occurs a large dextral sac (s.) apparently representing the cardiac dilatation of the stomach. Posteriorly the rectum (r.) descends obliquely towards the edge of the marginal fin, which the imperforate anus does not quite reach. The long narrow urocyst (u.) lies against the posterior wall of the rectum. The notochord is multi-columnar with largish cells, and is rather stout. From the pre-cranial vesicle (f.) the dorsal marginal fin rises in a gentle ascending curve till it reaches a point a little behind the pectorals, where its height is '48 mm., the total height of body with yolk and fin being 1'08 mm. Thence the fin descends gradually to the broad rounded caudal lobe, in which embryonic fin rays have appeared. The ventral fin has about the same dimensions as that part of the dorsal which is opposite to it. Just behind the anus the trunk is about '24, whilst the dorsal and ventral fins are each about '39 mm. in height. The pre-anal fin, extending nearly half-way along the yolk, is somewhat broader. The anterior three-quarters of the head and trunk is covered with profuse dendritic pigment of a bright gamboge-yellow colour; there is a very bright patch (p. b.) at the end of this region, from which ramifications extend on to the dorsal and ventral fins, anastomosing with a large chromatophore on each fin. The rest of the trunk is little pigmented. Round yellow chromatophores are distributed over the general surface of the yolk-sac, dendritic pigment covers the pre-cranial vesicle and pre-anal fins, and there are six and four large patches along the margins of the dorsal and ventral fins respectively.

A few small stellate black chromatophores occur on the fore- and mid-brain, about the commencement of the notochord, over the yolk-sac and along the ventral edge of the hinder third of the gut. Black pigment also occurs in faint lines along the sides of the pre-cranial vesicle. No black pigment occurs on the eye.

I cannot say anything definite as to the age of this larva, except that it is more than six hours old.
It is difficult to refer this specimen definitely to any species. The measurements of the ova of *Solea vulgaris* given by various authors are somewhat conflicting. M’Intosh and Prince (op. cit., p. 848) give 0.15 mm. (roughly about 1.125 mm.). A number which I pressed from a female and artificially fertilized measured between 1.31 mm. and 1.40 mm.; and others taken in the tow-nets at St. Andrews in June, 1890, varied between 1.25 mm. and 1.28 mm. Cunningham’s measurements (Reproduction and Development of Teleostean Fishes, p. 18) are 1.41 to 1.51 mm.*

Thus there seems to be in the single species a very great variation, perhaps to some extent governed by local conditions, as Cunningham’s specimens, from Plymouth, are much larger than any that have come under our notice here.

Of Raffaele’s soles, the ova of his undetermined species, 1. *Solea (?)* (op. cit., p. 63), approaches ours most closely in dimensions, being 1.4 mm. *Solea*, sp. A and B, are respectively 1.06 mm. and 1.23 mm. in diameter (pp. 43–45).

In the character of the vesicular layer of the yolk my egg differs from *Solea vulgaris*, as described and figured by M’Intosh and Prince, and as observed by myself at this place, in that the segments appear to be smaller and more numerous; but Cunningham (op. cit.) has shown that in this matter *Solea vulgaris* is subject to individual variation. In my form the segments persisted some time after hatching as conspicuous objects, a condition different to that indicated by M’Intosh and Prince.

As regards the oil-globules, the presence of groups of minute globules along the sides of and under the embryo is a marked character of *S. vulgaris*, and of Raffaele’s sp. A and B, whilst it is wanting in his sp. 1.

The presence of larger globules over the general yolk surface is peculiar, as though M’Intosh and Prince’s figure (op. cit., Pl. ii., fig. 11), shows that in *S. vulgaris* larger globules are present in the later stages of development (doubtless by coalescence of smaller), yet in that form they are grouped with the smaller ones, mostly about the ventral surface of the embryo, a condition which is not found in our form even after extrusion. The colour and arrangement of the pigment is very different from that of *S. vulgaris.*

The egg of *Solea variegata*,† described by Cunningham, approaches this form very closely in dimensions, being only 0.02 mm. smaller, but differs in the character of the oil-globules.

---

* In his “Treatise on the Common Sole,” Plymouth, 1890, p. 84, this observer gives the dimensions as 1.47 to 1.51 mm.
† M’Intosh and Prince (op. cit.) describe and figure the pigment of the larval *S. vulgaris* as a stone-grey, a condition in accordance with my own observations. Cunningham (“Treatise on the Common Sole,” pl. xvi., figs. 3 and 4) figures the pigment as a brilliant orange, and does not allude to the work of previous observers.
‡ In his recent work, Cunningham gives the dimensions of this egg as 1.28 to 1.36 mm., and figures both eggs and larvae.
The remarkable forward projection of the mid-brain in the larva seem to separate it from any other known form.

M’Intosh and Prince (op. cit., p. 851), call attention to a dorsal prominence of the optic lobes, imparting a hooded aspect to the head of a larval sole four days old, and Raffaele’s figure of the larva of Solea, sp. A, indicates a condition somewhat approaching that in our form. Sp. A also approaches ours in having a “lobo cefalico rigonfio” of the dorsal marginal fin, and the colour and character of its pigment appear almost the same. But sp. A not only has a much smaller ovum, but is much less elongated in its larval stage. M’Intosh and Prince (p. 850) mention a vesicular process over the brain in one example of S. vulgaris, but regard it as abnormal.

The spawning period of Raffaele’s species A and B extends over autumn, winter, and spring, and that of his species 1 from June to August.

Cunningham gives March, April, and May as the spawning period of S. vulgaris, an observation which presumably refers to southern waters. That the period may be extended on the Scottish coasts is apparent, from the fact that a ripe female was obtained by Professor M’Intosh on August 1, 1884.

During the six weeks with which this report deals we obtained a considerable number of soles from time to time, but they were all spent, males and females alike. A specimen of Solea variegata, obtained early in July, was also spent. Solea lutea appeared to be ripe during this period, but I have no accurate observations at present on its ova, as taken from the female, though I am inclined to regard a much smaller sole-like egg (species II. of this series) as belonging to that form.

The form before us may possibly be a monstrosity of Solea vulgaris, but it is difficult to regard it in that light, as it differs at once from that species in so many characters—characters which bring it nearer to the Mediterranean species A.

Solea lascaris, the lemon sole, is regarded by Day as identical with S. impar, one of the species examined by Raffaele (species A or B? op. cit., p. 43). The only other sole recorded from the west coast of Ireland is S. greenii,* a deep-water form, of which Mr. G. C. Bourne obtained a ripe female in July, 1889.

Species II.—Solea lutea (?) (Risso).

Pl. xlvi., figs. 9 and 10. Pl. li., figs. 46–52.

These small pelagic ova were obtained abundantly in the surface nets in Blacksod, Inver, Donegal, and Clew Bays, from the 15th June to the 8th July.

In appearance they exactly resemble Cunningham’s figure of the pelagic egg, which he attributes, doubtless correctly, to Solea variegata (op. cit., Pl. iii., fig. 15, p. 23), but the dimensions are smaller. The diameter is from 775 to 835 mm. (that

* Discovered by Mr. Green in the “Flying Fox” Expedition. 1889.
of S. variegata is 1.36 mm.). The shape is usually spherical, but some are ovoidal, having a long and short diameter of .835 and .775 mm. respectively. The numerous small oil-globules (o. g.) are restricted to the vegetative hemisphere, both in early (fig. 10) and advanced (fig. 9) stages, and are never aggregated at the sides of the embryo or under it, as in S. vulgaris.

The globules are much larger than those in the unfertilized egg of S. vulgaris, and are quite colourless. There is a cortical layer of yolk segments (c. v.) very conspicuous in the early ova,* but becoming less so as development proceeds, though they are still visible in the early larva (fig. 46).

Raffaele (op. cit., p. 64) describes and figures a pelagic egg, his undetermined species 2, which presents the closest possible resemblance to this form. Its diameter is .75 mm., thus differing very slightly in size from our form. It occurs at Naples sparingly in January; I think it more than possible that the two forms are identical, the resemblances outweighing the slight discrepancy in size.

The period of development in ovo, in the form before us, occupies about five days. The embryo is at first colourless, but pigment of a faint yellow colour, black by transmitted light, appears with the first development of the free caudal region (fig. 9).

It occurs in small rounded chromatophores on the top of the eyes and head, in a double line along each side of the trunk, and over the general surface of the yolk-sac. At this stage the otocysts have not appeared, and the lenses are not invaginated.

As development proceeds the pigment gains in brilliancy, becoming in the larva a bright-orange, brown by transmitted light.

The larva emerges at an early stage of development (fig. 46). The yolk (y.) is large and globular, there is no mouth, and the fore-brain is bent down to the anterior extremity of the yolk-sac. The olfactory apparatus cannot be made out; the eyes are of moderate size, and pigmentless, save for a few chromatophores over the retina. The otocysts (o.t.) are small and oval, and remote from the eye. The contour of the head is rounded, and the medulla rises somewhat above the plane of the top of the mid-brain. The cerebellum is somewhat large, but the pineal body is not visible.

The heart (h.) lies immediately behind the eyes, in a depression of the top of the yolk. It is partially constricted into auricle and ventricle, and is, as usual, directed to the left.

* These segments appear first at the animal pole, beneath the blastoderm, and extend gradually over the whole periphery of the yolk. A very early ovum, which I obtained at St. Andrews on the 30th of July, showed the oil-globules mostly arranged in a ring at the rim of the vesicular layer, which did not quite reach the equator. Their subsequent disposition may be in some way due to the extension of the segments.
The gut is somewhat large and tubular, except in the rectal region; it extends below the notochord a short way beyond the yolk; the narrow cord-like rectum (r.) descends vertically to the marginal imperforate anus (a.), at a short interval from the hind-wall of the yolk-sac. The oil-globules (v.g.) are, as a rule, restricted to the posterior region of the yolk, occupying the ventral and ventro-lateral surface of that region, having, as is frequent, undergone a migration backwards from their original positions.

The marginal fins are somewhat narrow, the dorsal and ventral being about 12 mm. each, except at the anterior extremity of the ventral, which descends on to the postero-ventral border of the yolk-sac, becoming thus somewhat deeper. The dorsal commences at the otocystic region; the caudal is short and rounded, with no embryonic rays. The pectoral fins have not appeared. The notochord is multi-columnar, with small cells.

The pigment, now a bright-orange colour (brown by transmitted light), occurs in small chromatophores over the head, along the back, and ventral post-anal region, over the yolk-sac, and on the posterior part of the gut, and at the anus. It forms a conspicuous bar (p.b.) across the trunk at the commencement of the posterior third of the total length. Chromatophores occur also on the dorsal, and sparingly along the edge of the ventral fin.

The total length at this stage is 2.02 mm., of which the pre-anal region occupies 0.895 mm., the anus (a.) being slightly anterior to median. It is probable that there is slight variation in the length of the larva on emerging.

A specimen about a day old (fig. 47), has a total length of 2.14 mm., the increase being entirely in the post-anal region. The yolk is slightly reduced.

At about two days old (fig. 48) the total length is the same as in the last stage. The yolk is further reduced, and the oil-globules are fewer in number. The snout is more forwardly directed, and the pineal body is conspicuous. The mid-brain has gained slightly in dorsal prominence. The otocysts are larger and ventrally convex. They have undergone a slight upward rotation on their posterior ends, and, by the shortening up of the hind-brain, are carried nearer to the eye.

The invagination of the stomatodeum has commenced. The pectorals have appeared as semicircular folds of epiblast (their bases parallel to the notochord), midway between the snout and the anus. The gut is dilated more conspicuously in the region of the future stomach (s.), and its thickened tubular character has extended some way down into the rectum. The chromatophores have now become stellate, and another pigment bar (p.b.) has appeared across the trunk midway between the anus and the bar noticed in the newly-hatched larva. The chromatophores of the yolk-sac are fewer, but larger than formerly, and those on the edge of the ventral fin have disappeared. The dorsal fin has extended forward to the mid-brain, and is much expanded, as are the ventral and short pre-anal fins.
Two days later (fig. 49) the yolk is still further reduced, and very few oil-globules remain. The total length is now 2.38 mm., the increase being still confined to the post-anal region. The mid-brain (m. b.) is more prominent dorsally, and the mouth (m.) forms a deep pit below the eyes. The lower jaw is short, and downwardly directed.

The otocysts are much larger. The gut is a little bent downwards in the middle of its course, and the rectum (r.), except a very short distal portion, is expanded and tubular. A considerable interval, due to the absorption of the yolk, now occurs between that structure and the rectum. The pectorals (p.f.) have increased in size; they are fan-shaped, and their bases are further forward than before, and have undergone a considerable rotation in the usual direction. The arrangement of the pigment is somewhat altered. The earliest pigment bar (p.b.) has been carried backwards with the elongation of the post-anal region. In front of it are three large pectinate patches along the dorsum, the most anterior lying above the anus. Similar ventral patches opposite the two dorsal ones, almost form two anterior bars. The anterior bar noticed in the larva of four days has disappeared. Large patches, varying in individuals, occur along the dorsal fin near its margin, the largest being in the anterior region. Lengthened patches occur along the ventral near its base, principally in the posterior region. In the specimen figured the dorsal does not extend so far forward as in the earlier stages shown. The pectorals are pigmented, and embryonic fin-rays have appeared in the caudal fin.

In older stages (shown in figures 50 and 51) the prominence of the mid-brain (m. b.) is still more marked; the heart is advanced, and the gut is longer and slightly convoluted; the anus is perforate; and a long urocyt (u.) has appeared behind the rectum. The pectoral fins are lobate and rayed. The otocysts (ot.) are larger, and somewhat rectangular and inferiorly concave. They are now close behind the eyes. There are no oil-globules left in the reduced yolk mass. A marked angulation of the dorsal fin occurs behind the pectorals.

The post-anal region of the trunk is very attenuated, and the marginal fins are much expanded.

Black pigment has commenced to appear in the eyes; and further changes have taken place in the arrangement of the yellow pigment.

The total length is now 2.98 mm., the increase being still almost entirely confined to the post-anal region.

The development of the jaw apparatus is much advanced, the lower jaw (m.k.) projects boldly forward, and is freely moveable. The hyoid and branchial arches are easily seen, but the latter are not as yet pectinate. The heart (h.) is closed and perfect. The gut is much lengthened and convoluted, and the liver (l.) is seen as a lobe-shaped body in the anterior part of the abdomen. There is a
Holt.—On the Eggs and Larve of Teleosteans.

conspicuous rectal valve \( r.v. \). The clavicle \( c.l. \) is conspicuous in front of the very large fan-shaped pectorals \( p.f. \), the rotation of which is now complete. The eyes are black at this stage. The caudal fin has become somewhat lanceolate, and the dorsal sends down a narrow strip in front of the mid-brain \( m.b. \).

The post-larval condition (fig. 52) is reached in eight or nine days. There is no great advance from the last stage, except that the liver \( l. \) is larger, and the gut more convoluted; whilst the dorsal fin is further expanded in the anterior region.

No black pigment has appeared except in the eyes, but the yellow pigment has become somewhat greenish. The total length is from 2.98 to 3.10 mm., there is a slight increase in the pre-anal length, which is now 96 mm. This is an extremely hardy species; with very little attention they were easily reared in small vessels to the post-larval condition. It is interesting that Professor M'Intosh obtained two eggs, apparently identical with these, in St. Andrews Bay in the early part of July of this year, and another occurred on the 30th of that month.

From the characters of the egg and larva I am inclined to think that the parent species is *Solea lutea*. This is, of course, mere conjecture, but it is perhaps permissible in view of the many sole-like characters that are met with.

The combination of a cortical layer of yolk segments with numerous small oil-globules is, as far as I know, confined to the eggs of various species of *Solea* and to Raffæle's undetermined species, No. 2, which is probably identical with this form. I know that *Solea lutea* breeds about the time these eggs were obtained, from having found a nearly ripe female of this species in Galway Bay on the 2nd June. Unfortunately, having much other work on hand, I did not examine its ova minutely, and can only say that they were very small.

Species III.—**Motella-like.**

Pl. xlvii., fig. 11.

Several specimens of this small pelagic egg were taken in the surface-net in Blacksod Bay on the 14th and 15th June.

The diameter is 66 mm.; the zona shows no peculiar features; the yolk \( y. \) is clear and homogeneous, and there is a single oil-globule \( o.g. \) in the usual position, exhibiting a pale greenish-yellow colouration, 14 mm. in diameter.

Of two ova examined one contains an early pigmentless embryo, from the sides of which faint transverse striæ extend outwards over the yolk-sac for a little distance. In the anterior region the yolk is a little separated from the yolk-sac, and a faint stellate striation occurs on the upper surface near the oil-globule.

In the other specimen (fig. 11) the embryo is more advanced, having a short
free caudal region, and exhibits no striation of the yolk-sac, which may probably be attributed in the other to ill-health.

Five small black chromatophores occur over the oil-globule, and the yolk-sac is very sparingly decorated in a similar manner. Small stellate black chromatophores occur on the top of the brain, and in a row along each side of the dorsum, except in the free caudal region, where there is a single median dorsal row. There is a prominence (i. s. a.) on either side of the anterior region of the body, which perhaps represents a lateral sense organ.

These ova were lost on the 17th June, by the upsetting of my aquaria in a heavy roll, and I never obtained any other specimens.

This form is rather smaller than the egg of Motella mustela, with a rather larger oil-globule, the colouration of which is distinctive. The pigmentation of the embryo is also more precocious than in M. mustela, and is differently arranged (cf. Brook, "The Development of Motella mustela," loc. cit.). It agrees with the egg of M. tricirrata in the arrangement of the pigment, and in the presence of colouration in oil globule, but differs in size, the egg of this species, according to Raffaele (op. cit., p. 37), having a diameter of .75 mm., with an oil-globule of .218 mm.

It seems probable that the present form is a Gadoid, possibly Motella cimbria.

Species IV.—Ctenolabrus rupestris (?)

Pl. xlviii., figs. 23 and 24. Pl. xlxi., figs. 28–30.

These pelagic ova occurred in the surface-net, in Blacksod Bay on the 15th June, and in Inver Bay on the 20th and 25th June. They were not abundant.

The egg is spherical, with a diameter of .835 mm., and the zona is thin and minutely pitted, the yolk translucent and homogeneous. There is no oil-globule. The perivitelline space is small. The younger stages exhibit no distinctive characters. Black pigment appears at the time when the free caudal region becomes noticeable (fig. 23), and is arranged in a row of small chromatophores along each side of the body, except in the caudal region. A few very minute pigment dots occur at intervals between the outer rows, and there are several larger chromatophores on the top of the brain.

A specimen obtained on the 20th June exhibited the first formation of the embryonic shield. Two days later the embryo was far advanced (fig. 24) having a free caudal region equal to the rest of its length. The body is very slender. The crystalline lens is fully formed; the heart beats actively. The otocysts (ot.) are visible as small ovoidal sacs, with otothls, remote from the eye. The lateral row of black chromatophores extends some way along the free caudal region.
The structure of the notochord (\textit{no.}), unicolumnar throughout at this stage, is clearly visible, and there is a broad marginal fin.

I was only successful in hatching one egg of this species, viz. one obtained on the 25th June. I examined the larva on the 29th June (figs. 28 and 29), when it appeared to be somewhat older than Agassiz and Whitman’s \textit{C. adspersus} of twenty-four hours (\textit{op. cit.}, Pl. ix.). The total length is 2:855 mm. The pre-anal length is 1:37 mm., and there is an interval of 0.62 mm. between the yolk and the anus; the post-anal length is 1.485 mm.

There are five pairs of lateral sense organs (\textit{l.s.o.}) as in \textit{C. adspersus}, of which the first pair occupies the same position as in the American species, viz. between the eyes and otocysts. The three remaining pairs, however, lie further back than in the newly hatched \textit{C. adspersus}, the second pair lying between the end of the yolk and the anal region, whilst the last three are placed at equal distances along the post-anal region. They represent probably some of those more numerous organs shown by Agassiz and Whitman (\textit{op. cit.}) in a larva some hours after hatching (Pl. ix., fig. 33). The third and fourth pairs are not quite symmetrical.

The greater part of the head projects forward in front of the yolk, terminating in a blunt snout. There is as yet no mouth. The pineal is easily seen, as are the precocious nasal sacs (\textit{ol.}), from which the nasal valves (\textit{n. v.}) already project clear of the contour of the head (fig. 30). The cerebellar fold is small. The otocysts (\textit{ot.}) are sub-circular and small, and as yet remote from the large unpigmented eyes. The pectorals (\textit{p.f.}) are visible as largish, semicircular folds of the lateral epiblast about half-way between the snout and anus.

The gut is slightly dilated below the pectoral fins. It runs back as a thick-walled tube below the notochord to the anal region, at which point it sends down a solid translucent cord-like limb (\textit{r.}) almost vertically, to the marginal and imperforate anus (\textit{a.}). The urocyt is not visible.

The notochord (\textit{no.}) presents the same remarkable structure as in \textit{C. adspersus}. Its anterior third, \textit{i.e.} the part overlying the yolk, is unicolumnar. At the commencement of the middle-third two cells begin to make their appearance in the same plane of transverse section, a condition which persists as far back as the caudal extremity, where, as is frequently the case in larval fishes, the notochord is irregularly unicolumnar. The cells of the anterior unicolumnar region have not the same bubble-like structure as is met with in the herring and sprat.

The dorsal marginal fin rises a little behind the otocyst and gradually attains its greatest height, a little more than that of the body, opposite the anus. The ventral fin is of the same dimensions as the dorsal, both tapering insensibly into the short and almost lanceolate embryonic caudal fin. Anteriorly the rectum (\textit{r.}) cuts off a pre-anal segment (\textit{p.a.f.}) from the ventral marginal fin, the margin of
which is incurve at the anus (a.). Pigment is confined to a double dorsal line of small black chromatophores, extending from the snout backwards along the anterior two-thirds of the body.

I think that these eggs and larva may be with little doubt referred to _Ctenolabrus rupestris_.

The egg is very little smaller than that of _C. adspersus_ (which measures 85 to 92 mm.).

The larva is also a little smaller. It will be seen from Agassiz and Whitman’s account (op. cit., p. 18) of _C. rupestris_, that in the pigment, contour of the larva, and sense organs, the two species present close resemblances, whilst the notochord, a feature of importance, has the same peculiar structure in both. That _C. rupestris_ occurs in the neighbourhood where these ova were obtained is apparent from Day’s account of their habitat (op. cit., vol. i., p. 265). I myself obtained some young specimens, but was not so fortunate as to get any sexually mature. Day mentions a female full of spawn taken at Dublin in June. The American species spawns from May to July.

These fish seem to be known (in common with the rest of the Labridæ) as gunners on the Mayo coast.

Species V.—Coris-like.

(Pl. xlviii., fig. 16; Pl. li., figs. 43–45.)

These ova occurred sparingly in the surface-net on the 20th June in Inver Bay, and on the 7th July at the Bull’s Mouth, Achill Island.

The diameter is from 805 mm. to 835 mm., and there is a single colourless oil-globule of 15 mm. In its early stages it is not easily distinguished from a slightly smaller ovum (species VIII.).

The shape is spherical (fig. 16), and the zona (z. r.) presents no feature of special interest. The perivitelline space (p. s.) is small, and the yolk (y.) is colourless, translucent, and homogeneous.

I have no observations on the development _in ovo_. The larva emerged on the 23rd from an egg taken on the 20th June.

The larva (fig. 43) is elongated. The total length (including the yolk and oil-globule) is 244 mm., the anus being slightly anterior to median (113 mm. from anterior end of yolk-sac). The flexure of the brain is not so apparent as in most early larva (from pelagic eggs), as the elongated yolk (y.), having the oil-globule (o. g.) at its anterior extremity, projects forward in front of the snout, thus to some extent preventing the flexure. The perforated region of the gut extends under the notochord some way behind the yolk, from which the narrow solid rectum (r.)
is separated by a considerable interval. The imperforate anus (a.) is marginal. There is a small urocyt (u.) in the usual position.

The eyes are of moderate size, unpigmented. The pineal (pn.) is visible; the cerebellar fold is small. The otocysts (ot.) are small, and somewhat conical dorsally, and as yet remote from the eye. The pectorals have not appeared. The dorsal marginal fin commences behind the otocysts, and reaches its greatest height, about 18 mm., a little behind the anal region. The ventral marginal, slightly less than the dorsal, is indented towards the anus, as is the pre-anal segment (p.a.f.). The caudal is broad and rounded, and slightly spatulate at this stage.

The pigment is all black, and is confined to the head and trunk. Largish stellate chromatophores are distributed sparingly and somewhat irregularly over the anterior two-thirds of the dorsal surface. A small chromatophore marks the hind-wall of the urocyt. A little behind the last dorsal, there are two stellate chromatophores on the ventral edge of the body, and a few small stellate chromatophores occur ventrally and laterally in the extreme caudal region.

A day later the larva (fig. 44) is only 3.8 mm. in total length. This decrease is due to the partial absorption of the yolk and withdrawal of its anterior extremity, with the oil-globule, to a point in rear of the fore-brain. The same cause has operated to increase the downward flexure of the brain (a condition the reverse of that which is met with in the development of most teleostean larvae), thus further decreasing the pre-anal length, which is now only 1.01 mm.

The post-anal length has, however, gained 0.06 mm. The yolk is now bluntly ovoidal. The gut shows a slight dilatation in the middle of its length (s.), and its tubular region extends a little further into the rectum. The pectorals (p.f.) have appeared in the usual position; they are as yet very small, little more than prominences of the lateral epiblast. A great deal of the pigment noticed on the previous day has disappeared; the head is altogether destitute of it, and the dorsal chromatophores are fewer in number, whilst some of them appear to have migrated to the lateral region. The extreme posterior end of the caudal region is slightly upturned, and the subnotochordal pigment is now dendritic, and extends on to the marginal fin. Embryonic caudal fin rays have appeared. The heart at this, as at the previous stage, occupies the usual position, and beats actively. The structure of the notochord (fig. 45) is somewhat characteristic. The cells (vacuoles) are large, and sometimes one, sometimes two, or even three occur in the same plane of transverse section. I was not successful in rearing this species to an older stage.

The ova and larvae of this form present a remarkable resemblance to those of Coris julis, Coris giofredi, and Julis luricca, as described and figured by Raffaele (op. cit., p. 35). Raffaele's ova, however, are smaller, having a diameter of
60–70 mm., with an oil-globule 16–18 mm. *C. giofredi* is regarded by Day (op. cit., vol. i., p. 269) as a synonym of *C. julis*. Hoffman (op. cit., p. 11) describes the ovum of *Julis vulgaris* as having a diameter of 75 mm., with an oil-globule of 15 mm., whilst the newly-hatched larva measures 1.77 mm.

*Coris julis* is the only one of these species that is known to be British, and it does not seem to have been recorded from Ireland. Centrolabrus, of whose development nothing is known, appears to be fairly abundant on the west coast.

I am inclined to regard this form as belonging to some member of the Labridae, and closely allied to *Coris*. The structure of its notochord presents considerable resemblance to that of *Ctenolabrus*. *Mullus surmulletus* and *M. barbatus* (see Raffaele, op. cit., pp. 20–22) are the only other forms which present any close resemblance to this in their earlier stages, but, besides differences of dimensions, there is in their ova a layer of cortical yolk segments, and the anus in the larva is nearer to the yolk.

Species VI.

(Pl. xlviii., fig. 17.)

This species is represented by only a single example, which was taken in the surface-net in Inver Bay on the 25th June.

The diameter is 1.13 mm., and there is a single oil-globule (*o. g.*) of 21 mm. The yolk is clear and homogeneous, and there is no colouration of any sort. Whilst agreeing with another unidentified egg, species VII., in measurements, it is at once distinguished from it by the large size of the perivitelline space (*p. s.*), and by the entire absence of pigment at a somewhat advanced stage.

My observations deal only with the stage shown in fig. 17. The embryo is about 1.14 mm. long, of which 30 belongs to the precaudal region. The eyes are large. I could not make out the otocysts, or the heart. The oil-globule is at the posterior end of the yolk (*y.*), which is 66 mm. long and 93 mm. broad.

In the presence of a single oil-globule and a large perivitelline space this egg approaches that of the pilchard (see Raffaele, op. cit., p. 55, and Cunningham's later Paper, p. 43), but differs from it in dimensions and in the absence of the reticulation of the periblast, which is characteristic of clupeoid ova.

Species VII.

(Pl. xlviii., fig. 18; Pl. xlix., figs. 25, 25a.)

A few ova, which appeared to belong to the same species, at the same stage of development, occurred in the surface-nets in Inver Bay on the 25th June.
The diameter varies from 1.07 to 1.13 mm.; and there is a single colourless oil-globule, 15—21 mm., occupying the usual position at the uppermost pole. The zona presents no features of special interest. The yolk is clear and homogeneous, and the perivitelline space is small.

The embryo at this stage (fig. 18) has a short, free caudal region bent up over the yolk. The otocysts (ot.) have appeared as small round sacs, with a double outline, in the usual position. The head and eyes are entirely unpigmented, but a number of minute black pigment dots extend along the trunk on either side of the notochord from the otocysts to the posterior extremity.

A few larger black stellate chromatophores occur over the oil-globule.

Development appears to be slow, and the species appears to be rather delicate. None of these eggs hatched, and only one survived till the 29th June.

The egg then lay at the bottom of the vessel, a phenomenon which I have frequently noticed in advanced ova reared in confinement in this laboratory (e.g. ova of sprat, gurnard, &c.), and one which appears to be in no way attributable to ill-health, as the larvae emerge and are not appreciably less robust than their fellows. That it is not due to a change in the specific gravity of the water is proved by the fact that it occurs even in continually running water of the same specific gravity. That moribund pelagic eggs should sink is easily intelligible, but it is hard to understand why this should also happen to perfectly healthy specimens. It is possibly brought about, in some instances, by the adherence to the zona of particles of dust, &c., which find their way into the aquaria; but appears to be a regular feature of development in some species, e.g. T. vipera (cf. Raffaele, op. cit., p. 30). The embryo (fig. 25) now appears almost ready for extrusion. The free caudal region is equal to the rest of the body. The eyes are large, and the otocysts have increased in size, and are vertically elongated, but as yet remote from the eyes. The pectorals (p.f.) have appeared as small semicircular folds in the usual position. The heart (h.) is large, and beats actively. The notochord (pl. xlix., fig. 25a) is stout, and its cells show a definite arrangement into a dorsal and ventral series, the bases to some extent interdigitating, but never approaching the cuneiform condition. The gut is large and perforate, and shows two dilatations in the region of the pectoral fins. It is also slightly expanded near the posterior extremity. The anus appears to lie just behind the yolk. The yolk is still large, and nearly spherical, the oil-globule (o.g.) now occupying a posterior position, in a well-marked periblastic pocket. A narrow marginal fin is visible in the free caudal region of the trunk. The cephalic integument and the whole of the surface of the yolk-sac (y.s.) is studded with minute tubercles, very conspicuous in profile.

I have noticed a similar condition in individuals of several species (e.g. Callionymus lyra, Clupea harengus, &c.). It is sometimes transitory, as in an early cottoid
larva, but it may more usually be looked upon as an indication of approaching moribundity.

The pigment is remarkable at this stage (fig. 25). It is of two colours:—(1) A deep bluish-black, perhaps the "nero violacee" of Raffaele, distributed in rounded chromatophores along the top of the head and dorsum (except the posterior fifth), and more sparingly in the renal region and over the oil-globule. (2) Bright reddish-brown, appearing much the same by reflected and transmitted light, very thickly scattered in small chromatophores all over the head and trunk, except the posterior fifth, where it is confined to the dorsal and ventral regions; it is less abundant on the eyes, and there are two small chromatophores, with the black, over the oil-globule. A little of this reddish pigment also occurs on the part of the yolk immediately adjacent to the head.

These ova present a close resemblance both in dimensions and pigmentation, to those of _Hemitripterus americanus_, identified by Agassiz and Whitman from a series of young forms obtained in the tow-nets.

The Scorpenidae, to which Hemitripterus belongs, are only represented on the Irish coast by _Scorpaena dactyloptera_ (a few specimens from deep water),* and _Sebastes norvegicus_, which is also rare.

The ova of the former probably resemble those of the Mediterranean species described by Raffaele, which adhere together in masses and are destitute of oil-globules, whilst Sebastes is a viviparous form.

Our ova also present some resemblances to those of Sargus and Box, described by Raffaele (op. cit., p. 23), who remarks that they spawn all the summer. Very little information as to the breeding season of the British Sparidae is forthcoming, Day's conjecture (op. cit., vol. i., p. 37) that _Pagellus centrodontus_ spawns in the winter months being probably due to a misconception of the rate of growth of the young.

Species VIII.

(Pl. xliv., fig. 27; Pl. l., fig. 36.)

This pelagic egg occurred in the surface-net in Blacksod Bay on the 14th, and in Clew Bay on the 30th June.

It is spherical, with a diameter of 1775 mm., and a single colourless oil-globule of 14 mm.

At the stage shown in fig. 27 the embryo is fairly advanced, but as yet the free caudal region is short. Small, rather pale yellow chromatophores occur sparingly over the general surface of the yolk sac, very abundantly over the

---

* The young of this species were obtained in considerable numbers, in 80 fathoms, off the Skellis in August, during the latter part of the cruise of the "Fingal."
oil-globule, and along the sides and on the head of the embryo, but less abundantly on the dorsum. A few small black chromatophores occur along the sides and on the head, and at intervals over the yolk-sac.

About twelve hours after hatching (fig. 36) the total length is 2·68 mm. The snout projects boldly in advance of the yolk. The olfactory apparatus (d.) is conspicuous; the eyes are large, but exhibit no black pigment as yet. The otocysts (ot.) small, and inferiorly conical, lie someway behind the eye. The pectorals (p.f.) have appeared, but are very small. The gut is dilated below the pectorals, and is tubular, and somewhat broad posteriorly; it projects beyond the yolk, and terminates blindly below the notochord at a distance of 955 mm. from the snout. The yolk (y.) is ovoidal, with postero-ventral oil-globule; the notochord (no.) is somewhat stout, and multi-columnar, with large cells.

The marginal fins are very broad, reaching their maximum a little anterior to median. The dorsal rises from the top of the mid-brain, and exhibits a remarkable angulation above the otocysts.

The black pigment has altogether disappeared, whilst the yellow has gained in brilliancy. It is now a vivid orange by reflected, and brownish yellow by transmitted, light. It covers the whole of the head and trunk in a network of dendritic chromatophores, except the extreme posterior region, which is devoid of pigment, and a broad bar about the middle of the post-anal region, which is almost equally so. The oil-globule (o.g.) and the adjacent parts of the ventral fin and yolk-sac, as well as the anterior region of the yolk-sac, the pectoral fins, and that part of the dorsal fin which lies below the angulation previously noticed, are also brilliantly pigmented.

I cannot say much as to the affinities of this form. The dimensions of the ovum agree well enough with Centropristis hepaticus (cf. Raffaele, op. cit. p. 19), but the larvae and the two forms present obvious differences.

Species IX.

(Pl. xlix., fig. 33.)

On the 13th June off Cleggan Head, near Innishbofin, and off the Bills, and on the 5th July in Keel Bay, Achill Island, a number of large pelagic ova were taken in the surface-net. I have referred these to a single species, as, though the variation in size between the largest and smallest is considerable, between intermediate specimens it is very slight, and I could see no other character to distinguish them from each other.

The egg is spherical, with a diameter of 1·49–1·64 mm., and there is a single colourless oil-globule of 24–30 mm. It is thus the largest egg of this series, being considerably larger than that of the grey gurnard.
The zona is thin, the yolk clear and homogeneous, and in the early stages the perivitelline space is small, and the whole egg is extremely translucent.

The species appears somewhat delicate, as none of the ova hatched, although several reached a late stage of development. They showed a tendency, at a comparatively late stage, to sink to the bottom of the vessel, and, after continuing to develop there for some time, became opaque and died. It would appear that the larva escapes in a more advanced condition than is usual in pelagic forms. The yolk is greatly reduced, leaving a very large perivitelline space (fig. 33, p. s.) before hatching, and the embryo appears older than the escaped larvae of many forms.

It is characterized, at the later stage examined (fig. 33), by the posterior position of the oil-globule (o. g.), and the great breadth and peculiar pigmentation of the marginal fins. The rectum (r.) lies close against the yolk, behind the oil-globule, and the perforate anus (a.) is marginal. The eyes are very large, the mid-brain (m. b.) dorsally prominent, and the otocysts (ot.) are elongated and inferiorly concave. The dorsal marginal fin extends forward in front of the fore-brain, rising abruptly; just behind the anus the trunk has a height of 27 mm., the ventral fin being 10 mm., and the dorsal about equal in height to the body.

Greenish pigment (ochreish-yellow by transmitted light) occurs in small chromatophores over the yolk-sac, and sparingly on the greater part of the head and trunk, and along the dorsal and ventral fins about the middle of their width. There are a few large black stellate chromatophores, with the greenish pigment, about the oil-globule, and smaller rounded black chromatophores occur over the yolk-sac, and dorsally and ventrally about the anal region of the trunk. A series of peculiar pectinate black chromatophores run along the margin of the embryonic fin backwards from the anal region. I could not see any signs of the pectoral fins.

I have no suggestion to offer as to the parent form. It is noteworthy that these eggs, too conspicuous to escape detection, were only obtained in comparatively open waters.

NOTE ADDED IN PRESS.

*Labrus maculatus* (p. 449).—I had overlooked the late Mr. J. Duncan Matthews's description of the nest, ova, and larvae of this species. The ova are about 1 mm. in diameter, and the newly-hatched larvae are 3-75 mm. long; they are decorated with black and yellow pigment.—("Report Fishery Board, Scotland, 1887," pp. 245-247, pl. xi.)
INDEX TO SPECIES.

IDENTIFIED.

<table>
<thead>
<tr>
<th>Species</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Callionymus lyra,</td>
<td>442</td>
</tr>
<tr>
<td>Cepola rubescens,</td>
<td>446</td>
</tr>
<tr>
<td>Clupea harengus,</td>
<td>456</td>
</tr>
<tr>
<td>Clupea sprattus,</td>
<td>455</td>
</tr>
<tr>
<td>Crenilabrus melops,</td>
<td>450</td>
</tr>
<tr>
<td>Gobius niger (?),</td>
<td>441</td>
</tr>
<tr>
<td>Labrus maculatus,</td>
<td>449</td>
</tr>
<tr>
<td>Lepadogaster bimaculatus,</td>
<td>447</td>
</tr>
<tr>
<td>Macrurus rapestris,</td>
<td>451</td>
</tr>
<tr>
<td>Merluccius vulgaris,</td>
<td>451</td>
</tr>
<tr>
<td>Nerophis æquoreus,</td>
<td>456</td>
</tr>
<tr>
<td>Nerophis lumbriciformis,</td>
<td>456</td>
</tr>
<tr>
<td>Pleuronectes cyanoglossus</td>
<td>455</td>
</tr>
<tr>
<td>Pleuronectes microcephalus</td>
<td>453</td>
</tr>
<tr>
<td>Rhombus lasius</td>
<td>452</td>
</tr>
<tr>
<td>Scomber scolion</td>
<td>437</td>
</tr>
<tr>
<td>Siphonostoma typhle</td>
<td>456</td>
</tr>
<tr>
<td>Syngnathus aequus</td>
<td>456</td>
</tr>
<tr>
<td>Trachinus vipera</td>
<td>437</td>
</tr>
<tr>
<td>Trigla gurnardus</td>
<td>440</td>
</tr>
</tbody>
</table>

UNIDENTIFIED.

<table>
<thead>
<tr>
<th>Species</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species I., Solea (?),</td>
<td>457</td>
</tr>
<tr>
<td>Species II., Solea lutea (?),</td>
<td>460</td>
</tr>
<tr>
<td>Species III., Motella-like,</td>
<td>464</td>
</tr>
<tr>
<td>Species IV., Ctenolabrus rupestris (?),</td>
<td>465</td>
</tr>
<tr>
<td>Species V., Coris-like,</td>
<td>467</td>
</tr>
<tr>
<td>Species VI,</td>
<td>469</td>
</tr>
<tr>
<td>Species VII,</td>
<td>469</td>
</tr>
<tr>
<td>Species VIII,</td>
<td>471</td>
</tr>
<tr>
<td>Species IX,</td>
<td>472</td>
</tr>
<tr>
<td>Table</td>
<td>Showing the Dimensions (X 40) of the Ova.</td>
</tr>
<tr>
<td>-------</td>
<td>----------------------------------------</td>
</tr>
</tbody>
</table>

**PELAGIC OVA.**
Figures 1 to 19.

**DEMERSAL OVA.**
20 to 22.

Where there is Variation in the Ova of a species, the average dimensions are shown.

---

**Species**

- Pleuronectes microcephalus
- Trachinus vipera
- Merluccius vulgaris
- Lepidogalaxias
- Calidris lutu
- Scophthalmus
- Cottus bairdi
- Clupea harengus
- Pleuronectes cycloides
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pouting
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclogaster
- Pleuronectes cyclo...
LETTERING ADOPTED IN ALL THE FIGURES.

<table>
<thead>
<tr>
<th>Letter</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.</td>
<td>anus</td>
</tr>
<tr>
<td>b.</td>
<td>air-bladder</td>
</tr>
<tr>
<td>b. b.</td>
<td>branchial bar</td>
</tr>
<tr>
<td>b. r.</td>
<td>blastodermic rim</td>
</tr>
<tr>
<td>cl.</td>
<td>clavicle</td>
</tr>
<tr>
<td>c. v.</td>
<td>epiblastic ridge connecting pectoral and pelvic fins</td>
</tr>
<tr>
<td>d. 1.</td>
<td>cortical vesicle or segments of yolk</td>
</tr>
<tr>
<td>d. 2.</td>
<td>site of permanent first dorsal fin</td>
</tr>
<tr>
<td>d. f.</td>
<td>permanent second dorsal fin</td>
</tr>
<tr>
<td>f.</td>
<td>precephalic vesicular expansion of dorsal fin</td>
</tr>
<tr>
<td>f. b.</td>
<td>fore-brain</td>
</tr>
<tr>
<td>fll.</td>
<td>filaments of attachment process</td>
</tr>
<tr>
<td>g. b.</td>
<td>gall-bladder</td>
</tr>
<tr>
<td>h.</td>
<td>heart</td>
</tr>
<tr>
<td>h.m.</td>
<td>hyomandibular cartilage</td>
</tr>
<tr>
<td>h.p.</td>
<td>hypural lobe of tail</td>
</tr>
<tr>
<td>h.s.</td>
<td>hyoid arch</td>
</tr>
<tr>
<td>k. v.</td>
<td>Kupffer's vesicle</td>
</tr>
<tr>
<td>l.</td>
<td>liver</td>
</tr>
<tr>
<td>l.s.o.</td>
<td>lateral sense organ</td>
</tr>
<tr>
<td>m.</td>
<td>mouth</td>
</tr>
<tr>
<td>m. b.</td>
<td>mid-brain</td>
</tr>
<tr>
<td>m. i.</td>
<td>micropyle (closed)</td>
</tr>
<tr>
<td>m. o.</td>
<td>medullis oblongata</td>
</tr>
<tr>
<td>n.</td>
<td>notochord</td>
</tr>
<tr>
<td>n. v.</td>
<td>nasal valve</td>
</tr>
<tr>
<td>o.g.</td>
<td>oil-globule. o.g. 1. minute aggregated globules. o.g. 2. larger scattered globules</td>
</tr>
<tr>
<td>o.l.</td>
<td>nasal sac</td>
</tr>
<tr>
<td>o.p.</td>
<td>opercular flap</td>
</tr>
<tr>
<td>o.t.</td>
<td>otocyst</td>
</tr>
<tr>
<td>p. a.f.</td>
<td>embryonic pre-anal fin</td>
</tr>
<tr>
<td>p. b.</td>
<td>pigment bar</td>
</tr>
<tr>
<td>p.f.</td>
<td>pectoral fin</td>
</tr>
<tr>
<td>p.f.</td>
<td>pelvic fin</td>
</tr>
<tr>
<td>p.n.</td>
<td>pineal body</td>
</tr>
<tr>
<td>p.s.</td>
<td>perivitelline space</td>
</tr>
<tr>
<td>p.v.f.</td>
<td>permanent ventral fin</td>
</tr>
<tr>
<td>r.</td>
<td>rectum</td>
</tr>
<tr>
<td>r.d.</td>
<td>rod-like attachment-process of zona</td>
</tr>
<tr>
<td>r.p.</td>
<td>rim of central pedicle of attachment</td>
</tr>
<tr>
<td>r.v.</td>
<td>rectal valve</td>
</tr>
<tr>
<td>s.</td>
<td>dilatation of gut in region of future stomach</td>
</tr>
<tr>
<td>s.t.</td>
<td>stratified inner layer of egg-capulse</td>
</tr>
<tr>
<td>u.</td>
<td>urocyt</td>
</tr>
<tr>
<td>v.m.</td>
<td>outer layer of egg-capulse; vitelline membrane of Brook</td>
</tr>
<tr>
<td>y.</td>
<td>yolk</td>
</tr>
<tr>
<td>y.s.</td>
<td>yolk-sac</td>
</tr>
<tr>
<td>z. r.</td>
<td>zona radiata</td>
</tr>
</tbody>
</table>

EXPLANATION OF PLATE XLVII.

Figs. 1 to 12.

[The pigment, except when otherwise specified, is shown as by reflected light.]

Figure

1. Egg of *Lepadogaster bimaculatus*, from side.
2, 3. Eggs of the same, from above.
4. Pedicile of attachment, and part of inferior region of zona of the same, more highly magnified.
5. Yolk of newly-hatched larva of the same, from below.
6. Newly-hatched larva of the same, from the side.
7. The same as fig. 6, from above.
8. Optical section of egg-capulse of *Trachinus vipera*.
9. Egg of Species II. *Solea lutea. (?)*
10. Egg of the same, less advanced.
11. Egg of Species III.
PLATE XLVIII.

ON THE EGGS AND LARVÆ OF TELEOSTEANS.
LETTERING ADOPTED IN ALL THE FIGURES.

a. . . . . anus.
  a. b. . . . air-bladder.
  b. . . . . blastoderm.
  b. b. . . . branchial bar.
  b. r. . . . blastodermic rim.
  c. . . . . . clavicle.
  c. r. . . . epiblastic ridge connecting pectoral and pelvic fins.
  c. v. . . . cortical vesicles or segments of yolk.
  d. 1. . . . site of permanent first dorsal fin.
  d. 2. . . . permanent second dorsal fin.
  f. . . . . . precephalic vesicular expansion of dorsal fin.
  f. b. . . . fore-brain.
  fl. . . . . . filaments of attachment process.
  g. b. . . . gall-bladder.
  h. . . . . . heart.
  h.m. . . . hyomandibular cartilage.
  hy. . . . . . hyopophysis of tail.
  h'y. . . . . . hyoid arch.
  h. v. . . . Kupffer's vesicle.
  l. . . . . . liver.
  l. s. o. . . lateral sense organ.
  m. . . . . . mouth.
  m. b. . . . mid-brain.
  m. c. . . . micropyle (closed).
  m. o. . . . medulla oblongata.
  n. o. . . . notochord.
  n. v. . . . nasal valve.
  n. g. . . . oil-globule. n. g. 1. minute aggregated globules. n. g. 2. larger scattered globules.
  n. s. . . . nasal sac.
  o. p. . . . opercular flap.
  o. t. . . . otocyst.
  p. a. f. . . embryonic pre-anal fin.
  p. b. . . . pigment bar.
  p. f. . . . pectoral fin.
  p. f. f. . . pelvic fin.
  p. t. . . . pineal body.
  p. v. . . . perivitelline space.
  p. v. f. . . permanent ventral fin.
  r. . . . . . rectum.
  r.d. . . . rod-like attachment-process of zona.
  r. p. . . . rim of central pedicle of attachment.
  r. v. . . . rectal valve.
  s. . . . . . dilatation of gut in region of future stomach.
  s.t. . . . . stratified inner layer of egg-capule.
  u. . . . . . urocyt.
  v. m. . . . outer layer of egg-capule : vitelline membrane of Brook.
  y. . . . . . yolk.
  y. s. . . . yolk-sac.
  z. r. . . . zona-radiata.

EXPLANATION OF PLATE XLVIII.

Figs. 13 to 24.

[The pigment, except when otherwise specified, is shown as by reflected light.]

Figure.
13. Ripe unfertilized egg of Rhombus lavis.
14. Fertilized egg of the same (?), advanced, from the tow-net.
15. Egg of Trachinus vipera, with embryo showing the paired fins (p. f. and pl. f.) connected by a continuous ridge (c. r.). Pigment and oil-globules omitted.
16. Egg of Species V., early stage.
17. Advanced egg of Species VI.
18. Egg of Species VII.
19. Egg of Pleuroneoctes microcephalus, with unpigmented embryo.
20. Part of zona of the same, flattened, Z. D. Oc. 2, Cam. luc.
21. The same, seen obliquely, in living egg.
22. Ripe unfertilized egg of Cepola rubescens : dead.
23. Egg of Species IV. Ctenolabrus rupstris. (?)
24. More advanced egg of the same, more highly magnified.

[4]
PLATE XLIX.

ON THE EGGS AND LARVAE OF TELEOSTEIANS.
LETTERING ADOPTED IN ALL THE FIGURES.

\[a\ldots\ldots\] anus.
\[a. b.\ldots\ldots\] air-bladder.
\[b.\ldots\ldots\] blastoderm.
\[b. b.\ldots\ldots\] branchial bar.
\[b. r.\ldots\ldots\] blastodermic rim.
\[c.\ldots\ldots\] clavicle.
\[c. v.\ldots\ldots\] epiblastic ridge connecting pectoral and pelvic fins.
\[d. 1.\ldots\ldots\] site of permanent first dorsal fin.
\[d. 2.\ldots\ldots\] permanent second dorsal fin.
\[f.\ldots\ldots\] precephalic vesicular expansion of dorsal fin.
\[f. b.\ldots\ldots\] fore-brain.
\[f l.\ldots\ldots\] filaments of attachment process.
\[g. b.\ldots\ldots\] gall-bladder.
\[h.\ldots\ldots\] heart.
\[h m.\ldots\ldots\] hyomandibular cartilage.
\[h p.\ldots\ldots\] hypural lobe of tail.
\[h y.\ldots\ldots\] hyoid arch.
\[l. r.\ldots\ldots\] kidney of vesicle.
\[l.\ldots\ldots\] liver.
\[l. s. o.\ldots\ldots\] lateral sense organ.
\[m.\ldots\ldots\] mouth.
\[m. b.\ldots\ldots\] mid-brain.
\[m i.\ldots\ldots\] micropyle (closed).
\[m. o.\ldots\ldots\] medulla oblongata.
\[n. o.\ldots\ldots\] notochord.
\[n. r.\ldots\ldots\] nasal valve.
\[o. g. 1.\ldots\ldots\] oil-globule. o. g. 2. minute aggregated globules.
\[o. s.\ldots\ldots\] nasal sac.
\[o p.\ldots\ldots\] opercular flap.
\[o t.\ldots\ldots\] otocyst.
\[p. n. f.\ldots\ldots\] embryonic pre-anal fin.
\[p. n.\ldots\ldots\] pigment bar.
\[p. f.\ldots\ldots\] pectoral fin.
\[p l. f.\ldots\ldots\] pelvic fin.
\[p n.\ldots\ldots\] pinnaal body.
\[p. s.\ldots\ldots\] perivitelline space.
\[p. v. f.\ldots\ldots\] permanent ventral fin.
\[r.\ldots\ldots\] rectum.
\[r d.\ldots\ldots\] rod-like attachment-process of zona.
\[r. v.\ldots\ldots\] rim of central pedicle of attachment.
\[r. v.\ldots\ldots\] rectal valve.
\[s.\ldots\ldots\] dilatation of gut in region of future stomach.
\[s t.\ldots\ldots\] stratified inner layer of egg-capsule.
\[u.\ldots\ldots\] urocyt.
\[v. m.\ldots\ldots\] outer layer of egg-capsule : vitelline membrane of Brook.
\[y.\ldots\ldots\] yolk.
\[y. s.\ldots\ldots\] yolk-sac.
\[z. r.\ldots\ldots\] zona radiata.

EXPLANATION OF PLATE XLIX.

Figs. 25 to 33.

[The pigment, except when otherwise specified, is shown as by reflected light.]

Figure

25. Egg of Species VII, four days older than fig. 18, pl. 11.
25a. Part of notochord of same, more highly magnified.
26. Egg of Species I. Solea. (?)
27. Egg of Species VIII.
28, 29. Larva of Species IV. Clenoloburus rupestris. (?) Some time after hatching. Ventral and profile view.
30. Cephalic region of same, more highly magnified.
31. Egg of Trachinus vipera, early stage, x 40.
32. Advanced stage of same, more highly magnified.
33. Egg of Species IX. (by transmitted light.)

[6]
PLATE L.

ON THE EGGS AND LARVAE OF TELEOSTEANS.
LETTERING ADOPTED IN ALL THE FIGURES.

| a  | anus.          | no. | notochord. |
| b  | air-bladder.  | u, v. | nasal valve. |
| b. | blastoderm.   | o. g. | cil-globule. |
| b. b. | branchial biv. | o. g. 1. minute aggregated globules. |
| b. r. | blastodermic rim. | o. g. 2. larger scattered globules. |
| cl. | clavicle.     | ol.   | nasal sac.  |
| c. r. | epiblastic ridge connecting pectoral and pelvic fins. | op.   | opercular flap. |
| c. v. | cortical vesicles or segments of yolk. | ot.   | otocyst.    |
| d. 1. | site of permanent first dorsal fin. | p. a. f. | embryonic pre-anal fin. |
| d. 2. | permanent second dorsal fin. | p. b. | pigment bar. |
| f.  | pro-encephalic vesicular expansion of dorsal fin. | p. f. | pectoral fin. |
| fl. | filaments of attachment process. | p. n. | pineal body. |
| g. b. | gall-bladder. | p. p. | perivitelline space. |
| h. | heart.        | p. v. f. | permanent ventral fin. |
| h. m. | hyomandibular cartilage. | r.   | rectum. |
| h. p. | hypural lobe of tail. | r. f. | red-like attachment-process of zona. |
| h. y. | hyoid arch.  | r. p. | rim of central pedicle of attachment. |
| k.  | Kupffer's vesicle. | r. v. | rectal valve. |
| l.  | liver.        | s.    | dilatation of gut in region of future stomach. |
| m. s. o. | lateral sense organ. | s. t. | stratified inner layer of egg-capeaule. |
| n.  | mouth.        | u.    | urocyt. |
| m. b. | mid-brain.   | v. m. | outer layer of egg-capule: vitelline membrane of Broch. |
| m. i. | micropyle (closed). | y.    | yolk. |
| m. o. | medulla oblongata. | y. v. | yolk-sac. |
| z. r. | zona-radiata. |

EXPLANATION OF PLATE I.

Figs. 34 to 39.

[The pigment, except when otherwise specified, is shown as by reflected light.]

Figure.

34. Larva of Species I. Solea. (?) Profile view.
35. Dorsal view of anterior region of the same.
36. Larva of Species VIII., about twelve hours after hatching.
37. Larva of Trachinus vipsa, shortly after hatching.
38. The same, early post-larval stage.
39. Larva of Pleuronectes microcephalus (by transmitted light).
PLATE LI.

ON THE EGGS AND LARVAE OF TELEOSTEANS.
LETTERING ADOPTED IN ALL THE FIGURES.

\begin{align*}
a. & \quad \text{anus.} \\
b. & \quad \text{air-bladder.} \\
c. & \quad \text{epiblastic ridge connecting pectoral and pelvic fins.} \\
d. & \quad \text{cortical vesicles or segments of yolk.} \\
e. & \quad \text{site of permanent first dorsal fin.} \\
f. & \quad \text{permanent second dorsal fin.} \\
g. & \quad \text{fore-brain.} \\
h. & \quad \text{filaments of attachment process.} \\
i. & \quad \text{gall-bladder.} \\
j. & \quad \text{heart.} \\
k. & \quad \text{byomandibular cartilage.} \\
l. & \quad \text{hyopertzeal valve.} \\
m. & \quad \text{hyoid arch.} \\
n. & \quad \text{Kupffer's vesicle.} \\
o. & \quad \text{uterus.} \\
p. & \quad \text{lateral sense organ.} \\
q. & \quad \text{mouth.} \\
r. & \quad \text{mid-brain.} \\
s. & \quad \text{micropyle (closed).} \\
t. & \quad \text{medulla oblongata.} \\
u. & \quad \text{notochord.} \\
v. & \quad \text{nasal valve.} \\
w. & \quad \text{oil-globules.} \\
x. & \quad \text{minute aggregated globules.} \\
y. & \quad \text{larger scattered globules.} \\
z. & \quad \text{nasal sac.} \\
a. & \quad \text{nasal sac.} \\
a. & \quad \text{orbicular flap.} \\
b. & \quad \text{otocyst.} \\
c. & \quad \text{embryonic pre-anal fin.} \\
d. & \quad \text{pigment bar.} \\
e. & \quad \text{pectoral fin.} \\
f. & \quad \text{pelvic fin.} \\
g. & \quad \text{pinna.} \\
h. & \quad \text{peritoneal space.} \\
i. & \quad \text{permanent ventral fin.} \\
j. & \quad \text{rectum.} \\
k. & \quad \text{rod-like attachment-process of zona.} \\
l. & \quad \text{rim of central pedicle of attachment.} \\
m. & \quad \text{rectal valve.} \\
n. & \quad \text{dilatation of gut in region of future stomach.} \\
o. & \quad \text{stratified inner layer of egg-capsule.} \\
p. & \quad \text{urocyst.} \\
q. & \quad \text{outer layer of egg-capsule; vitelline membrane of Brook.} \\
r. & \quad \text{yolk.} \\
s. & \quad \text{yolk-sac.} \\
t. & \quad \text{zona radiata.}
\end{align*}

EXPLANATION OF PLATE LII.

Figs. 40 to 45.

[The pigment, except when otherwise specified, is shown as by reflected light.]

Figure

40, 41. Newly-hatched larva of Callionymus lyra. Ventral and profile views.
42. Larva of the same, about twelve hours old.
43. Larva of Species V., shortly after hatching.
44. The same larva, one day older.
45. Part of notochord of the same, more highly magnified.
PLATE LII.

ON THE EGGS AND LARVÆ OF TELEOSTEANS.
EXPLANATION OF PLATE LIII.

Figs. 46 to 52.

[The pigment, except when otherwise specified, is shown as by reflected light.]

Figure.
46. Newly-hatched larva of Species II. Solea lutea. (?) Ventral view.
47. Larva of the same, about one day old. Profile view.
48. Larva of the same, two days old.
49. Larva of the same, four days old (by transmitted light).
50. Larva of the same, about six or seven days old (by transmitted light).
51. Anterior region of larva about six days old, more highly magnified.
52. Early post larval stage of the same, eight or nine days old.
TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1-25.—November, 1877, to September, 1883. (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1-2.—August, 1879, to April, 1882. (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1-14.—September, 1883, to November, 1887. (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.


3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.


5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.


7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleostean. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.
VIII.

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

VIII.


DUBLIN:

PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

LONDON: WILLIAMS AND NORRIS.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK, PRINTERS TO THE SOCIETY.

1891.
VIII.


[Read November 19, 1890.]

In the construction of telescopic objectives for visual use, it is necessary to satisfy two conditions only, assuming, of course, that the quality of the material and the workmanship of the surfaces be perfect. These two conditions are, that the chromatic and spherical aberrations be corrected as nearly as possible. In the construction of objectives suitable for photography, it is necessary to satisfy a third condition, viz. freedom from coma in the lateral pencils, in order to obtain as perfect a field as possible.

If the lateral images of an ordinary telescopic objective be examined, it will be found that at a very small distance from the centre of the field of view, say 20' or 30', a very sensible coma is apparent: this coma is toward the axis, and gives the images the appearance shown in fig. 1. Owing to the small field usually employed, or necessary to be employed, in astronomical telescopes, this coma is rarely seen, but observers are quite familiar with the appearance of a star, when the objective is out of adjustment, and requires alteration to place its axis coincident with the axis of the tube. The appearance in that case is the same as that mentioned above, for the images that the observer then sees in the centre are really due to lateral pencils; and it is by the position of this coma that the observer determines the direction in which the necessary adjustment must be made, in order to utilize the central pencil, and get the best results. In determining the best form to be given to these objectives, it was necessary to keep in view the ultimate purpose for which the photographs obtained by them were intended. Some forms of objectives give a very widely-spread coma, with a very distinct nucleus in the lateral images, and photographs taken with such objectives are sometimes very deceptive. For, if no large stars be upon
the plate, the images appear very perfect for a considerable distance from the centre, the fact being that the coma is so widely spread, and consequently weak in intensity, that it is invisible in the case of the smaller stars. On consideration, however, it will be seen that such images would be useless for the purpose required, viz. accurate measurements. The image of a small star would only be that of its nucleus, while the image of a large star would include the coma which extends in this case not symmetrically on each side of the nucleus, but almost altogether on the side toward the centre; consequently the distances of all large stars from a central point would measure too small, as compared with those of stars of less magnitude.

It is not possible to obtain absolutely round images of stars anywhere on a plate, except at or near the centre; but it is evidently necessary that whatever departure from a perfect circle the image may be, it must be symmetrical on each side of a tangential, as well as of a radial line cutting its centre (see fig. 2). That is to say, if C be the centre of the field, the image of the star must be symmetrical on both sides of the lines AB, CD. This, then, is the condition that must be satisfied in photographic objectives, as well as those mentioned before as necessary to be satisfied in the case of visual objectives, viz. freedom from chromatic and spherical aberrations.

In addition to the conditions above mentioned which it is necessary should be satisfied in the case of all photographic objectives, one more condition insisted on in the case of the objectives for the International Survey was, that all objectives should be within a very small percentage of the same focal length.

A little consideration will show that the imposing of these two additional conditions increased in a very high degree the labour in the construction of the objectives. It is convenient in considering the various alterations in the form of objectives to imagine the glass flexible, and capable of being bent out of its normal state to any other required form. Taking the form of the ordinary visual objective to start with, which with the more usually used qualities of glass is almost a bi-convex crown with a plano-concave flint fitting as in fig. 3, it is necessary, in order to eliminate the coma, that the crown be either bent forwards on edge as in fig. 4, or the flint bent backwards as in fig. 5. In other words,
that the two lenses be of such a form as would touch in centre if placed close together. By continuing the bending a point is reached at which the coma is cured; if we go further we obtain coma outwards. When the proper balance of coma is obtained we have an objective of approximately the form shown in fig. 6.* But, unfortunately, whichever course we adopt, either that of bending forward the crown or bending backward the flint, the correction for spherical aberration is destroyed. Bending forward the crown renders it (the crown) a lens of greater positive spherical aberration, and bending back the flint renders it (the flint) a lens of less negative aberration. In either case the spherical aberration of the whole is rendered strongly positive.

Again, in order to correct the objective for coincidence of the active chemical rays, it is necessary either to increase the power of the crown, or reduce the power of the flint; and this again introduces more positive spherical aberration into the objective, the result being a lens, corrected for chemical rays, corrected for coma, but under-corrected by a considerable quantity for spherical aberration. In an ordinary visual objective if the spherical aberration be found to be under-corrected, a modification of the form of either of the components should be made in order to correct this, but in this case all four curves are already fixed in order to fulfil the three conditions of focal length, chromatic aberration, and spherical aberration, consequently there is no latitude for further alteration. The total power of the combination is already fixed in order to fulfil the condition of focal length. The proportion of the power of crown to flint is already a fixed quantity in order that the chemical rays be united. If therefore the total power of the combination, and the proportional power of crown to flint be fixed, the actual powers of crown and flint are also fixed quantities. Lastly, the proportion of power on each surface of crown and flint, i.e. the form of the lens, is either fixed, or variable only in such directions as will not sensibly alter the correction for spherical aberration of the whole combination, that is to say, the correction for coma may be made as before stated, either by bending forward the edge of the crown, or bending back the edge of the flint, or by a combination of both, but in any case the correction for spherical aberration is reduced.

As there is no possibility of altering the curves of any surface of the objective without destroying the correction for one or other of the foregoing, the only possibility of correcting the spherical aberration is by figuring the surfaces to a form other than that of a sphere, and this is the course I was obliged to adopt when using this particular form of objective.

* The same effect on coma can also be obtained by separating the crown and flint, but in most cases the amount of separation required is excessive, and introduces more positive spherical aberration than the other method.
During the course of my investigations on these objectives, I worked out another form which gives very admirable results, and without as much or indeed any sensible forcing of the curves out of the spherical form. This objective is shown in fig. 7. In this form the flint is the outermost, and receives the parallel rays; the two inside curves are, as in the other form, so proportioned that they would touch in the centre; and the outside of the crown is nearly plano. This lens when corrected for coincidence of the chemical rays and for coma, is very nearly correct for spherical aberration also, and therefore its preparation is less troublesome than the form first described. If the inside curves were made to coincide there would be coma, but its direction would be the reverse of that given by the first described form, viz. it would be from, instead of towards, the centre of the field of view. In the vicinity of smoky cities this form might be objected to. Having the flint glass exposed to the influence of the air, it is more likely to be injured than if the crown were outermost. This form corrected for visual rays would make an admirable objective for transit instruments, or in any case where a large field is required.

The testing and correcting of these photographic objectives is much more troublesome than that of visual objectives. In visual objectives, the judging as to the perfection of the chromatic and spherical aberrations is altogether a matter of experience of the eye of the observer. A very few moments of favourable observation on a star or small point of light is sufficient to enable the experienced eye to judge of the fault to be corrected in the case of visual objectives, but in the case of the photographic objective no visual observations are of any use whatever, except that the state of the chromatic aberration can be roughly estimated by observing through various coloured glasses, or better still, through a film of ammonio-oxide, or ammonio-nitrate of copper; but the amount of outstanding colour is so great that no judgment can be formed of the state of the spherical aberration, and for the final tests photographs must be taken at every step of the process. When it is remembered that a clear sky and the utmost perfection of driving mechanism in the most perfect order is necessary in order to obtain these photographs, it can easily be imagined how very great are the difficulties in the preparation of the object-glasses.

Every step in the final corrections and final adjustments require a photograph to be taken, and consequently some of the simpler adjustments which are generally made within the space of an hour or so in the case of visual objectives, require in the case of photographic objectives a series of photographs to be taken, sometimes in consequence of broken weather, extending over several days, or even weeks.

As I have mentioned before, the final and crucial test for these object-glasses
is that of its performance on celestial objects. Many trials and experiments were made to get satisfactory artificial stars for testing these glasses, but although these are amply sufficient and perfectly satisfactory for testing visual objectives, they have not been found of so much use in the testing of photographic objectives. They were used largely in the earlier process, and in case of bad weather were a considerable help in forwarding the work more quickly than could have been done were it necessary always to wait for fine nights. But for final tests nothing but the natural star was perfectly satisfactory. During the testing of seven of these objectives a considerable amount of experience in celestial photography has been obtained, and I take occasion to remark that my experience does not tally exactly with that of Dr. Gill respecting the influence of atmospheric disturbance on the photographed images of the stars. He has stated that, with an exposure of over five minutes, as perfect, or very nearly as perfect, star-plates can be obtained on nights when the atmosphere is highly disturbed as on those when the air is perfectly steady. My experience goes to corroborate this so far as the large stars are concerned, but not as respects the small stars, and I think this is easily explained. Bright stars with long exposures imprint images on the photographic plate of considerable diameter. It is not necessary to discuss whether this increase of diameter is due to some form of halation, or chemical action; the fact remains that the longer the exposure the larger the image printed on the plate by any star. Consequently it is easy to understand that atmospheric disturbance which causes, as all observers know, a flickering and wavering, and general unsteadiness of the image, will have little or no effect on the photographic image in the brighter stars, because the amount of that wavering will always be far less than, and well contained within, the area of the surface which these brighter stars occupy on the plate; but, in case of small stars, and more particularly with very small stars, it is impossible to conceive that a point of light which would under favourable circumstances imprint itself as a speck of not more than $\frac{1}{7}$th to perhaps $\frac{1}{10}$th of an inch in diameter would produce equally perfect impressions on the plate if, during exposure, it wavered about over an area considerably more than its own diameter, and this is, as all observers know, the case on nights of bad definition. I was certainly surprised to find the very excellent images that were obtained of the larger and even moderate-sized stars on nights of exceedingly bad definition, but my experience shows that the images of smaller stars suffer very decidedly from the effect of atmospheric disturbance.

It may be interesting to record here that trials of a form of objective suitable for use either for a visual or a photographic purpose, proposed by Sir George G. Stokes have proved satisfactory. By separating the lenses of an ordinary visual objective, such as fig. 3, a point will be reached when the necessary correction for photographic rays will be obtained, but the spherical aberrations will then be
strongly positive. Sir George Stokes' suggestion is to grind the crown rather more convex on the inside than the outside, leaving the power of both crown and flint as before. The result of this will be to introduce a little positive spherical aberration. Let that be corrected by figuring the lens. When required for photographic use the lenses are separated as far as necessary to correct for photographic rays, and the crown lens is then reversed. The crown is now in a position of lower (positive) spherical aberration, and this balances the amount of aberration introduced by the separation. This has been successfully tried with small-sized objectives.
TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1-25.—November, 1877, to September, 1883. (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1-2.—August, 1879, to April, 1882. (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1-14.—September, 1883, to November, 1887. (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.
3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.
5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.
7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleostei. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LI. (February, 1891.) 4s. 6d.
10. The Slugs of Ireland. By R. F. Schaff, Ph.D., B.Sc., Keeper of the Natural History Museum, Dublin. With Plates. [In the Press.]
THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

IX.


DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

LONDON: WILLIAMS AND NORRAGATE.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK, PRINTERS TO THE SOCIETY.
1891.

Price Two Shillings.
THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

IX.

LUNAR RADIANT HEAT, MEASURED AT BIRR CASTLE OBSERVATORY,
DURING THE TOTAL ECLIPSE OF JANUARY 28, 1888. BY OTTO
BOEDDICKER, Ph.D. With an Introduction by The Earl of Rosse, K.P., LL.D., F.R.S.,
&e., President of the Royal Dublin Society. Plates LIII. to LV.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORGATE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.
1891.
IX.


[Read February 18, 1891.]

INTRODUCTION.

Some years ago it was suggested that it would be desirable to turn the large Reflectors at Parsonstown, armed with the thermopile, upon the moon, with the view of detecting, and, if possible, measuring its radiant heat. Several attempts to do so had been made elsewhere, but without encouraging results. Melloni had employed a lens of three feet aperture of imperfect quality, but sufficiently good for the purpose. Owing, however, to the large absorption of heat by glass he obtained no very certain indications, his pile could not have received any of the less refrangible heat rays through the glass, but it appeared quite possible that with a speculum of equal aperture far more decided and really interesting and instructive results might be arrived at. Accordingly, I procured a thermopile of four elements, with surface of face half an inch square, from Messrs. Elliott, fixed it in the principal focus of a concave reflector of three and a-half inches aperture and three inches focus, and placed the whole in my three-foot telescope, the concave mirror being situated at the focus, and directed towards the speculum. Thus the whole of the Moon's radiant heat (and light) which entered the three-foot tube was concentrated upon a spot of one-third of an inch in diameter, on the centre of the face of the pile. At first the indications were very uncertain. They were so masked by accidental disturbances that they could be detected with certainty only by taking the mean of a series of readings with the telescope directed towards the Moon, and comparing it with that of a series with the telescope turned away from the Moon. I then procured a second pile from Messrs. Elliott, fitted it and a similar concave reflector close beside the first, and placed both piles, but with poles in reversed position, in the same circuit with the galvanometer. Thus, by turning the telescope, so that the Moon's image fell...
alternately upon each pile, the effect sought for was nearly doubled, while extraneous disturbing effects tended generally to counteract one another. Still the needle was at all times more or less, and often very unsteady, though by taking means of a long series of alternate readings it was found possible, not only to demonstrate the existence of a very appreciable amount of radiation, but even roughly to estimate its variation with the phase and form, a curve generally representing that variation. The results were published in the *Proceedings* of the Royal Society, No. 112, 1869.

During the following season the experiments were pursued with modified apparatus; and, under the idea that the annoying disturbances of the needle still subsisting were largely due to an inequality of power between the two piles, these were replaced by thermocouples of home manufacture, selected out of a number, so as to be as nearly alike as possible.* They are described in the *Proceedings* of the Royal Society, No. 122, 1870; the results were published in the *Proceedings*, No. 123, 1870. In addition to another heat-curve, which, notwithstanding the modifications of the piles, does not give a more precise determination, I was able by the interposition of a sheet of glass to show in the above communication that the Moon's heat differed materially from the Sun's in that it contained a much larger proportion of rays of low refrangibility. From the very rapid diminution of the heat towards New Moon it was probable that at that phase the remaining heat would be scarcely if at all appreciable, and from these two facts I concluded that the heat which I had been attempting to measure was heat received by the Moon from the Sun, but only re-radiated after part of it had been absorbed by the lunar surface, and then emitted as dark rays of heat. At the same time, so far as could be gathered from these rough determinations the maximum of heat did not take place as might, perhaps, have been expected to an appreciable degree after the maximum of light, that is after Full Moon. Some rough determinations of the proportion between lunar and solar radiation were also made.

At this stage Dr. Copeland, who had taken up the post of Astronomical Assistant in my Observatory, began to devote much labour and patience to the investigation, using the same apparatus, only refitted and adjusted, as I had employed in the season 1869–70. He formed a more concordant series of mean results, and having fully reduced them, and having by long series of observations at largely varying altitudes obtained a curve for the absorption of heat by our atmosphere, he was able to produce a more reliable phase-curve for heat.

The determinations of the quality of the radiation by interposition of a sheet

---

* The thermopiles of bismuth, and an alloy of 12 bismuth to 1 tin were replaced about three and a-half years ago by thermopiles of iron and German silver, the wire of commerce being used in each case.
of glass were repeated, and they confirmed, as far as possible, the former results. The phase-curve strengthened the previous impression that no appreciable interval existed between the time of maximum of light and of the maximum of heat; on the contrary, from some unexplained cause the maximum of heat seemed to occur somewhat before Full Moon.

Dr. Copeland’s determinations, together with his discussion of them, were published in the *Philosophical Transactions* for 1873.

The striking result having been arrived at that the maximum of heat did not lag behind Full Moon, it appeared desirable to proceed a step further, and as a more rigid test to try how far the minimum of heat, which presumably existed during the progress of a lunar eclipse coincided with, or came later than the middle of that eclipse. Every visible lunar eclipse was eagerly waited for. The first occasion on which we were able to obtain a glimpse of the Moon during an eclipse was on November 14, 1872. The eclipse was only partial. The Moon was at a low and a diminishing altitude, and clouds interfered much. The heat radiation was, however, observed rapidly to decline during its progress, apparently as much as the light.

On October 4th, 1884, the next favourable opportunity occurred.* Dr. Boeddicker was on the spot with the apparatus in position from the commencement of the penumbra until forty minutes after the last contact with the penumbra. Clouds intervened until twenty-three minutes before totality, when the sky became perfectly clear, and remained so until the end of the observations. The heat as before diminished, and increased again nearly proportionally to the light, becoming inappreciable on reaching the limits of totality. The minimum of heat apparently fell later than that of illumination. But the most remarkable thing was that while during the short interval between the first contact with the penumbra and the commencement of total phase all appreciable radiation vanished, between the end of total phase and the last contact with the penumbra, and even forty minutes later the heat had not returned to the standard for Full Moon, being deficient by about twelve per cent. This we failed to explain, where we might expect to do so, by any derangement of the apparatus, nor could we trace it to any physical cause. The above observations were published in these *Transactions* for 1885 (vol. iii., series 2).

The next opportunity, an exceptionally favourable one, occurred on January 28, 1888. The sky was not obscured at all during the whole progress of the eclipse, and the same anomaly of the heat not returning to its standard value, even 1 hour 40 minutes after the last contact with the penumbra was observed. Also

* A total eclipse had meanwhile taken place on August 23, 1877, but owing to many interruptions from clouds, and the low altitude of the Moon, no advance was made. See *Copernicus*, vol. i., p. 22.
the radiation which we began to measure 1 hour 5 minutes before the first contact with the penumbra seemed to begin to decrease almost immediately; and even if the first observation be excluded, yet the decrease of heat seemed to begin as early as 15 minutes before the commencement of the eclipse. These results would appear to be particularly interesting as suggesting a terrestrial atmosphere much more extensive than it has generally been supposed to be which intercepts the Sun's rays of heat long before any part of the Moon has reached the Earth's shadow. We would much desire another opportunity for attacking the subject. As, however, it is exceedingly unlikely that the possibility of measuring the heat during an eclipse under similarly favourable meteorological conditions will soon recur here, and as it does not seem profitable to spend more time in getting a slightly more accurate phase-curve, it seems desirable that the present communication should close the series. If we pursue the subject of radiant heat further, it will be by making a new departure with apparatus modified so as if possible to combine greater sensibility with greater freedom from extraneous influences, varying also the methods, and extending the subjects and objects of investigation.

Dr. Boeddicker has devoted a great amount of time and labour to the fullest reductions, and to the formation of the theoretical curve for the Moon's light, possibly more than was justified by the probable errors of the observations, but as the occasion was quite an exceptional one it appeared best to leave nothing undone to get the utmost out of the night's work.

**Lunar Radiant Heat.**

I.—The Observations of 1888 and their Reduction.

1. As mentioned by Lord Rosse in his introduction to this Paper, my observations in 1884—the first really successful series of heat-observations during an eclipse—showed the striking anomaly, that 38 minutes after the last contact with the penumbra, the lunar heat still fell short of the Full Moon value by 13.2%. Though I never doubted the reality of this very unexpected result, yet others did so; and the fact that the value for the lunar heat corresponding to Full Moon could not be obtained on the same night before the beginning of the eclipse (the Moon rose eclipsed, and clouds intervened till 23 minutes before the beginning of the total phase), but had to be deduced from extra-eclipse observations, gave a certain strength to these doubts. For it is well known how the state of the atmosphere affects these observations, and renders conclusions from one night to another difficult and uncertain. It became, therefore, most desirable to carry these observations on during an eclipse which could be watched at Birr Castle.
Observatory during the whole of its course. Such an opportunity occurred on the
28th January, 1888, and was again exceptionally favoured by the weather, the
sky being perfectly clear (without any wind) the whole night through.

2. The mode of observing was essentially the same as in 1884. The
thermopiles of 1888, however—single thermic junctions—had been newly made
by Lord Rosse for the occasion, and were very considerably more sensitive than
the former ones. Consequently, one important alteration could be made, namely,
each pile was exposed for 30 seconds sidereal time only (against one minute in
1884); or, in other words, the galvanometer was read off every half minute, as
this time sufficed to obtain the maximum deflection. The labour of observing
was divided in such a way that Lord Rosse watched the thermopiles, and the
driving clock of the telescope, while I took all the readings of the galvanometer.
The alternate exposing of the thermopiles, which is readily done by simply
raising and lowering the telescope (of three-feet aperture) was done by an
assistant, the signal for it being given by me every 30 seconds by means of an
electric bell. The reading off of the galvanometer was carried on as far as possible
continuously during the whole of the eclipse. Some interruptions could, however,
not be avoided, and may be here at once enumerated.

3. Preliminary observations were taken from $3^h$ 20' 2'' to $3^h$ 25' 2'', and from
$4^h$ 6' 7'' to $4^h$ 11' 7'' sidereal time. The continuous series commenced at $4^h$ 16' 7''.
No observations were obtained from:—$4^h$ 37' 2'' to $4^h$ 39' 2'' (the zero point of the
galvanometer had to be changed); $5^h$ 6' 2'' to 7' 7'' (three readings were missed, the
signal not being understood by the assistant at the telescope); $5^h$ 14' 2'' to 20' 2''
(the clock-sector had to be wound back); $5^h$ 38' 2'' to 38' 7'' (one reading was
missed); $5^h$ 48' 7'' to 6' 0' 2''; 6' 15' 7'' to 22' 7''; 6' 25' 7'' to 45' 7'' (the driving-
clock stopped through the slipping off of a band). From 6' 45' 7'' till 8' 23' 2'',
which period embraces the time from 16' 3'' after the beginning, till 15' 6'' after
the end of totality, a number of galvanometer readings were taken. Since,
however, it became practically impossible to make sure of the lunar image being
concentrated on the thermopiles (owing to the extreme faintness of the eclipsed
moon), these observations, though given further on, could not be utilized for
the construction of the final heat-curve. Observations began again at 8' 28' 2'',
and lasted till 11' 52' 7'', with the following interruptions:—$9^h$ 18' 2'' to 23' 2''
(the clock-sector had to be wound back); $9^h$ 26' 7'' to 27' 7'' (one reading was
missed); $9^h$ 50' 7'' to 52' 2'' (two readings were missed); $10^h$ 49' 2'' to $11^h$ 19' 2''
(observing was stopped for thirty minutes). It will be perceived from the above
that observing was practically carried on from $7^h$ 19'' till $15^h$ 45'' mean time
Greenwich, during which period I read off the galvanometer altogether 638
times.
4. As in 1884, the differences of the consecutive readings of the galvanometer were taken together in groups of ten, and the mean of each group was assumed to represent the heat-effect corresponding to the time of the sixth of the eleven readings which furnish the ten differences. Owing to the observations forming an all but uninterrupted series, this grouping was proceeded with from difference to difference, so that the epochs of the heat values vary generally speaking by 0·5\textsuperscript{m} sidereal time only. Thus each reading was submitted to exactly the same treatment; and 473 values for the lunar heat were obtained. Of these 446 were available for the construction of the final heat curve. The first value, namely, corresponding to $3^h 22\cdot7^m$ (or $1^h 4\cdot2^m$ before the first contact with the penumbra) was excluded, as the Moon was still very low at that time, and situated, as seen from the Observatory, over the town of Parsonstown, so that but little reliance can be placed on it. And further, the values recorded during totality were excluded (as mentioned above) because the thermopiles were obviously not fully exposed to the lunar rays.

It may here be remarked that in the preliminary notes of these heat-observations which I communicated to Nature (No. 953, vol. xxxvii., February 2, 1888), and to the Astronomische Nachrichten (No. 2828, February 25, 1888) the observation of $3^h 22\cdot7^m$ was not excluded. The values given in the latter journal, being expressed in per cents. of the now excluded value, have, consequently, all to be corrected according to the present detailed publication.

5. The following Tables give the eclipse-observations in full. Their arrangement agrees strictly with Table I. in these Transactions for October, 1885, p. 323, containing the results of 1884. Any necessary explanations will be found on pp. 501 and 502.
### TABLE I.

**LUNAR HEAT DURING THE TOTAL ECLIPSE OF JANUARY 28, 1888.**

<table>
<thead>
<tr>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>VII.</th>
<th>VIII.</th>
<th>IX.</th>
<th>X.</th>
<th>XI.</th>
<th>XII.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sideral Time.</td>
<td>G.</td>
<td>P. E.</td>
<td>h</td>
<td>m</td>
<td>°</td>
<td>s</td>
<td>G.</td>
<td>log (R^2)</td>
<td>log (p^2)</td>
<td>e.</td>
<td>Sld. Time from Middle of Eclipse</td>
</tr>
<tr>
<td>---</td>
<td>-----</td>
<td>------</td>
<td>---</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>----------</td>
<td>----------</td>
<td>---</td>
<td>----------------</td>
</tr>
<tr>
<td>3 22-7</td>
<td>530-0</td>
<td>± 7-0</td>
<td>68-2</td>
<td>726-3</td>
<td>0-0013</td>
<td>0-0000</td>
<td>2-70</td>
<td>- 3 55-9</td>
<td>722-3</td>
<td>..</td>
<td>..</td>
</tr>
<tr>
<td>4 9-2</td>
<td>555-5</td>
<td>13-1</td>
<td>61-6</td>
<td>652-5</td>
<td>.0010</td>
<td>..</td>
<td>27</td>
<td>9-3</td>
<td>648-9</td>
<td>658-0</td>
<td>+ 9-1</td>
</tr>
<tr>
<td>16-2</td>
<td>555-9</td>
<td>5-1</td>
<td>60-2</td>
<td>665-1</td>
<td>..</td>
<td>..</td>
<td>16</td>
<td>2 59-3</td>
<td>661-6</td>
<td>655-3</td>
<td>- 5-8</td>
</tr>
<tr>
<td>17</td>
<td>554-6</td>
<td>6-1</td>
<td>1</td>
<td>663-0</td>
<td>..</td>
<td>..</td>
<td>16</td>
<td>58-3</td>
<td>655-5</td>
<td>655-3</td>
<td>- 4-2</td>
</tr>
<tr>
<td>20-2</td>
<td>554-3</td>
<td>6-1</td>
<td>0</td>
<td>662-1</td>
<td>..</td>
<td>..</td>
<td>15</td>
<td>3</td>
<td>658-8</td>
<td>654-1</td>
<td>- 4-7</td>
</tr>
<tr>
<td>21-2</td>
<td>555-3</td>
<td>5-8</td>
<td>59-9</td>
<td>652-8</td>
<td>..</td>
<td>..</td>
<td>15</td>
<td>57-8</td>
<td>659-4</td>
<td>653-6</td>
<td>- 5-8</td>
</tr>
<tr>
<td>21-7</td>
<td>557-3</td>
<td>6-9</td>
<td>8</td>
<td>664-2</td>
<td>..</td>
<td>..</td>
<td>14</td>
<td>56-8</td>
<td>660-7</td>
<td>652-7</td>
<td>- 8-0</td>
</tr>
<tr>
<td>22-2</td>
<td>558-0</td>
<td>7-0</td>
<td>7</td>
<td>664-5</td>
<td>..</td>
<td>..</td>
<td>14</td>
<td>3</td>
<td>661-0</td>
<td>652-2</td>
<td>- 8-8</td>
</tr>
<tr>
<td>23-7</td>
<td>559-5</td>
<td>6-3</td>
<td>7</td>
<td>665-9</td>
<td>..</td>
<td>..</td>
<td>13</td>
<td>55-8</td>
<td>662-4</td>
<td>661-8</td>
<td>- 10-6</td>
</tr>
<tr>
<td>23-2</td>
<td>557-2</td>
<td>3-1</td>
<td>6</td>
<td>662-8</td>
<td>..</td>
<td>..</td>
<td>13</td>
<td>3</td>
<td>659-4</td>
<td>651-2</td>
<td>- 8-2</td>
</tr>
<tr>
<td>24-2</td>
<td>554-9</td>
<td>8-4</td>
<td>5</td>
<td>659-4</td>
<td>..</td>
<td>..</td>
<td>12</td>
<td>54-8</td>
<td>656-0</td>
<td>650-7</td>
<td>- 5-3</td>
</tr>
<tr>
<td>24-4</td>
<td>552-8</td>
<td>3-2</td>
<td>5</td>
<td>658-2</td>
<td>..</td>
<td>..</td>
<td>12</td>
<td>3</td>
<td>654-6</td>
<td>650-0</td>
<td>- 4-6</td>
</tr>
<tr>
<td>25-2</td>
<td>552-8</td>
<td>9-8</td>
<td>4</td>
<td>655-7</td>
<td>..</td>
<td>..</td>
<td>11</td>
<td>55-8</td>
<td>652-2</td>
<td>649-4</td>
<td>- 2-8</td>
</tr>
<tr>
<td>25-2</td>
<td>550-2</td>
<td>11-4</td>
<td>3</td>
<td>652-4</td>
<td>..</td>
<td>..</td>
<td>11</td>
<td>3</td>
<td>648-9</td>
<td>648-6</td>
<td>- 0-3</td>
</tr>
<tr>
<td>26-2</td>
<td>548-5</td>
<td>11-6</td>
<td>2</td>
<td>649-8</td>
<td>..</td>
<td>..</td>
<td>11</td>
<td>52-8</td>
<td>646-5</td>
<td>648-0</td>
<td>+ 1-6</td>
</tr>
<tr>
<td>27-2</td>
<td>540-9</td>
<td>3-4</td>
<td>0</td>
<td>639-3</td>
<td>..</td>
<td>..</td>
<td>09</td>
<td>3</td>
<td>635-0</td>
<td>645-7</td>
<td>+ 9-7</td>
</tr>
<tr>
<td>28-2</td>
<td>542-8</td>
<td>8-3</td>
<td>58-9</td>
<td>638-6</td>
<td>..</td>
<td>..</td>
<td>09</td>
<td>50-8</td>
<td>635-3</td>
<td>645-0</td>
<td>+ 9-7</td>
</tr>
<tr>
<td>29-2</td>
<td>540-9</td>
<td>3-7</td>
<td>2</td>
<td>640-4</td>
<td>..</td>
<td>..</td>
<td>08</td>
<td>3</td>
<td>637-2</td>
<td>641-1</td>
<td>+ 6-9</td>
</tr>
<tr>
<td>29-2</td>
<td>546-1</td>
<td>10-8</td>
<td>8</td>
<td>640-0</td>
<td>..</td>
<td>..</td>
<td>08</td>
<td>49-8</td>
<td>640-7</td>
<td>643-2</td>
<td>+ 2-6</td>
</tr>
<tr>
<td>32-2</td>
<td>547-1</td>
<td>11-4</td>
<td>7</td>
<td>644-9</td>
<td>..</td>
<td>..</td>
<td>08</td>
<td>3</td>
<td>641-6</td>
<td>642-4</td>
<td>+ 0-8</td>
</tr>
<tr>
<td>32-2</td>
<td>550-1</td>
<td>10-3</td>
<td>7</td>
<td>648-0</td>
<td>0-0010</td>
<td>..</td>
<td>07</td>
<td>48-8</td>
<td>641-8</td>
<td>641-5</td>
<td>- 3-3</td>
</tr>
<tr>
<td>30-2</td>
<td>544-4</td>
<td>8-9</td>
<td>6</td>
<td>652-5</td>
<td>0-0002</td>
<td>..</td>
<td>07</td>
<td>3</td>
<td>649-2</td>
<td>640-6</td>
<td>- 8-6</td>
</tr>
<tr>
<td>31-2</td>
<td>557-3</td>
<td>7-6</td>
<td>5</td>
<td>655-1</td>
<td>..</td>
<td>..</td>
<td>06</td>
<td>3</td>
<td>651-6</td>
<td>638-8</td>
<td>- 12-8</td>
</tr>
<tr>
<td>32-2</td>
<td>549-4</td>
<td>22-6</td>
<td>4</td>
<td>645-4</td>
<td>..</td>
<td>..</td>
<td>06</td>
<td>40-8</td>
<td>641-9</td>
<td>637-8</td>
<td>- 4-1</td>
</tr>
<tr>
<td>32-2</td>
<td>540-1</td>
<td>28-1</td>
<td>3</td>
<td>634-0</td>
<td>..</td>
<td>..</td>
<td>05</td>
<td>3</td>
<td>630-6</td>
<td>636-9</td>
<td>+ 6-3</td>
</tr>
<tr>
<td>33-2</td>
<td>540-7</td>
<td>28-3</td>
<td>2</td>
<td>634-3</td>
<td>..</td>
<td>..</td>
<td>05</td>
<td>45-8</td>
<td>631-0</td>
<td>635-8</td>
<td>+ 4-8</td>
</tr>
</tbody>
</table>

**Remarks:**
### Boeddicker—On Lunar Radiant Heat.

<table>
<thead>
<tr>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>VII.</th>
<th>VIII.</th>
<th>IX.</th>
<th>X.</th>
<th>XI.</th>
<th>XII.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>h m</td>
<td>558-8</td>
<td>± 27-4</td>
<td>58-1</td>
<td>628-8</td>
<td>0-0009</td>
<td>0-0000</td>
<td>2-04</td>
<td>-2 44-8</td>
<td>625-5</td>
<td>633-4</td>
<td>+ 7-9</td>
<td>No observations from 4th 37-2m to 29-2m. 5 Differences before and 5 Differences after the interruption.</td>
</tr>
<tr>
<td>34:2</td>
<td>554-5</td>
<td>26-6</td>
<td>0</td>
<td>625-6</td>
<td>..</td>
<td>..</td>
<td>0-03</td>
<td>..</td>
<td>622-3</td>
<td>632-4</td>
<td>+ 10-1</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>537-8</td>
<td>28-6</td>
<td>0</td>
<td>629-1</td>
<td>..</td>
<td>..</td>
<td>0-03</td>
<td>..</td>
<td>625-8</td>
<td>631-3</td>
<td>+ 5-5</td>
<td></td>
</tr>
<tr>
<td>38:2</td>
<td>543-2</td>
<td>16-3</td>
<td>57-5</td>
<td>632-8</td>
<td>..</td>
<td>..</td>
<td>1-98</td>
<td>..</td>
<td>629-5</td>
<td>623-0</td>
<td>- 6-5</td>
<td></td>
</tr>
<tr>
<td>41:7</td>
<td>529-8</td>
<td>16-2</td>
<td>0</td>
<td>611-2</td>
<td>..</td>
<td>..</td>
<td>9-7</td>
<td>..</td>
<td>608-0</td>
<td>613-9</td>
<td>+ 5-9</td>
<td></td>
</tr>
<tr>
<td>42:2</td>
<td>522-8</td>
<td>18-1</td>
<td>56-9</td>
<td>606-1</td>
<td>..</td>
<td>..</td>
<td>9-5</td>
<td>..</td>
<td>603-0</td>
<td>612-5</td>
<td>+ 9-5</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>518-3</td>
<td>19-4</td>
<td>.8</td>
<td>600-5</td>
<td>..</td>
<td>..</td>
<td>9-5</td>
<td>..</td>
<td>597-3</td>
<td>611-2</td>
<td>+ 13-9</td>
<td></td>
</tr>
<tr>
<td>43:2</td>
<td>521-5</td>
<td>16-2</td>
<td>.8</td>
<td>603-9</td>
<td>..</td>
<td>..</td>
<td>9-4</td>
<td>..</td>
<td>600-6</td>
<td>609-8</td>
<td>+ 9-2</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>526-4</td>
<td>20-7</td>
<td>7</td>
<td>600-1</td>
<td>..</td>
<td>..</td>
<td>9-4</td>
<td>..</td>
<td>595-0</td>
<td>589-0</td>
<td>+ 2-4</td>
<td></td>
</tr>
<tr>
<td>44:2</td>
<td>525-9</td>
<td>20-7</td>
<td>7</td>
<td>608-5</td>
<td>..</td>
<td>..</td>
<td>9-3</td>
<td>..</td>
<td>603-3</td>
<td>607-0</td>
<td>+ 1-7</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>525-5</td>
<td>20-5</td>
<td>.6</td>
<td>607-4</td>
<td>..</td>
<td>..</td>
<td>9-3</td>
<td>..</td>
<td>594-2</td>
<td>595-0</td>
<td>+ 1-4</td>
<td></td>
</tr>
<tr>
<td>45:2</td>
<td>516-8</td>
<td>22-7</td>
<td>.5</td>
<td>597-0</td>
<td>0-0008</td>
<td>..</td>
<td>9-3</td>
<td>..</td>
<td>593-9</td>
<td>604-1</td>
<td>+ 10-2</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>509-1</td>
<td>24-2</td>
<td>.4</td>
<td>587-8</td>
<td>..</td>
<td>..</td>
<td>9-2</td>
<td>..</td>
<td>584-6</td>
<td>582-0</td>
<td>+ 18-0</td>
<td></td>
</tr>
<tr>
<td>46:2</td>
<td>517-1</td>
<td>20-7</td>
<td>.4</td>
<td>590-8</td>
<td>..</td>
<td>..</td>
<td>9-2</td>
<td>..</td>
<td>593-0</td>
<td>601-0</td>
<td>+ 7-4</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>518-9</td>
<td>20-6</td>
<td>.3</td>
<td>584-4</td>
<td>..</td>
<td>..</td>
<td>9-2</td>
<td>..</td>
<td>595-3</td>
<td>599-6</td>
<td>+ 4-3</td>
<td></td>
</tr>
<tr>
<td>47:2</td>
<td>519-7</td>
<td>26-1</td>
<td>.2</td>
<td>599-1</td>
<td>..</td>
<td>..</td>
<td>9-1</td>
<td>..</td>
<td>600-0</td>
<td>598-1</td>
<td>+ 2-1</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>524-1</td>
<td>24-2</td>
<td>.2</td>
<td>603-7</td>
<td>..</td>
<td>..</td>
<td>9-1</td>
<td>..</td>
<td>600-5</td>
<td>596-4</td>
<td>- 4-1</td>
<td></td>
</tr>
<tr>
<td>48:2</td>
<td>519-4</td>
<td>27-4</td>
<td>.1</td>
<td>593-3</td>
<td>..</td>
<td>..</td>
<td>9-0</td>
<td>..</td>
<td>596-2</td>
<td>594-9</td>
<td>+ 4-7</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>509-7</td>
<td>25-6</td>
<td>.0</td>
<td>586-5</td>
<td>..</td>
<td>..</td>
<td>9-0</td>
<td>..</td>
<td>583-4</td>
<td>592-3</td>
<td>+ 9-8</td>
<td></td>
</tr>
<tr>
<td>49:2</td>
<td>508-2</td>
<td>22-9</td>
<td>.0</td>
<td>582-5</td>
<td>..</td>
<td>..</td>
<td>9-0</td>
<td>..</td>
<td>579-4</td>
<td>591-7</td>
<td>+ 12-3</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>504-9</td>
<td>20-7</td>
<td>55-9</td>
<td>580-3</td>
<td>..</td>
<td>..</td>
<td>8-8</td>
<td>..</td>
<td>577-3</td>
<td>590-0</td>
<td>+ 12-7</td>
<td></td>
</tr>
<tr>
<td>50:2</td>
<td>513-7</td>
<td>27-9</td>
<td>.8</td>
<td>590-5</td>
<td>..</td>
<td>..</td>
<td>8-8</td>
<td>..</td>
<td>587-3</td>
<td>588-2</td>
<td>+ 0-9</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>522-1</td>
<td>20-2</td>
<td>.7</td>
<td>599-5</td>
<td>..</td>
<td>..</td>
<td>8-8</td>
<td>..</td>
<td>586-4</td>
<td>586-3</td>
<td>- 10-1</td>
<td></td>
</tr>
<tr>
<td>51:2</td>
<td>517-1</td>
<td>18-5</td>
<td>.7</td>
<td>593-4</td>
<td>..</td>
<td>..</td>
<td>8-7</td>
<td>..</td>
<td>590-3</td>
<td>584-6</td>
<td>- 5-7</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>519-0</td>
<td>19-1</td>
<td>.6</td>
<td>590-3</td>
<td>..</td>
<td>..</td>
<td>8-7</td>
<td>..</td>
<td>582-1</td>
<td>582-7</td>
<td>- 9-4</td>
<td></td>
</tr>
<tr>
<td>52:2</td>
<td>529-7</td>
<td>18-3</td>
<td>.5</td>
<td>596-9</td>
<td>..</td>
<td>..</td>
<td>8-6</td>
<td>..</td>
<td>593-7</td>
<td>550-7</td>
<td>- 13-0</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>518-2</td>
<td>18-3</td>
<td>.5</td>
<td>593-7</td>
<td>..</td>
<td>..</td>
<td>8-6</td>
<td>..</td>
<td>580-6</td>
<td>578-4</td>
<td>- 12-2</td>
<td></td>
</tr>
<tr>
<td>53:2</td>
<td>526-4</td>
<td>12-0</td>
<td>.4</td>
<td>602-9</td>
<td>..</td>
<td>..</td>
<td>8-5</td>
<td>..</td>
<td>599-8</td>
<td>570-1</td>
<td>- 23-7</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>526-4</td>
<td>12-0</td>
<td>.3</td>
<td>602-6</td>
<td>..</td>
<td>..</td>
<td>8-5</td>
<td>..</td>
<td>599-5</td>
<td>574-0</td>
<td>- 25-6</td>
<td></td>
</tr>
<tr>
<td>54:2</td>
<td>518-9</td>
<td>18-9</td>
<td>.3</td>
<td>603-7</td>
<td>..</td>
<td>..</td>
<td>8-4</td>
<td>..</td>
<td>597-7</td>
<td>571-7</td>
<td>- 19-9</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>514-1</td>
<td>26-0</td>
<td>.2</td>
<td>587-9</td>
<td>..</td>
<td>..</td>
<td>8-4</td>
<td>..</td>
<td>584-9</td>
<td>569-1</td>
<td>- 15-8</td>
<td></td>
</tr>
<tr>
<td>55:2</td>
<td>501-4</td>
<td>20-3</td>
<td>.1</td>
<td>576-2</td>
<td>..</td>
<td>..</td>
<td>8-3</td>
<td>..</td>
<td>573-3</td>
<td>566-9</td>
<td>- 6-4</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>502-4</td>
<td>18-9</td>
<td>.1</td>
<td>573-7</td>
<td>..</td>
<td>..</td>
<td>8-3</td>
<td>..</td>
<td>570-9</td>
<td>564-2</td>
<td>- 6-7</td>
<td></td>
</tr>
<tr>
<td>56:2</td>
<td>501-0</td>
<td>18-9</td>
<td>.0</td>
<td>571-9</td>
<td>..</td>
<td>..</td>
<td>8-3</td>
<td>..</td>
<td>569-0</td>
<td>561-5</td>
<td>- 7-5</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>493-1</td>
<td>18-0</td>
<td>54-9</td>
<td>562-6</td>
<td>..</td>
<td>..</td>
<td>8-2</td>
<td>..</td>
<td>559-8</td>
<td>559-0</td>
<td>- 0-8</td>
<td></td>
</tr>
<tr>
<td>I. Sideral Time</td>
<td>II. G.</td>
<td>III. P. E.</td>
<td>IV. z.</td>
<td>V. $G_r$</td>
<td>VI. log $p^3$</td>
<td>VII. log $R^2$</td>
<td>VIII. $e$</td>
<td>IX. Sid. Time from Middle of Eclipse</td>
<td>X. $G_s^*$</td>
<td>XI. Curve minus Observ.</td>
<td>Remarks</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>-------</td>
<td>------------</td>
<td>-------</td>
<td>--------</td>
<td>---------------</td>
<td>---------------</td>
<td>--------</td>
<td>---------------------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>h m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 57:2</td>
<td>457:2</td>
<td>19:8</td>
<td>54:8</td>
<td>555:5</td>
<td>0:0008</td>
<td>0:0000</td>
<td>1:82</td>
<td>-2 21:3</td>
<td>552:7</td>
<td>550:2</td>
<td>+ 3:5</td>
<td></td>
</tr>
<tr>
<td>1 7</td>
<td>460:4</td>
<td>20:7</td>
<td>8</td>
<td>547:5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>81</td>
<td>544:8</td>
<td>553:8</td>
<td>+ 9:0</td>
<td></td>
</tr>
<tr>
<td>50:2</td>
<td>475:3</td>
<td>18:7</td>
<td>7</td>
<td>544:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>80</td>
<td>542:1</td>
<td>550:9</td>
<td>+ 8:8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>476:7</td>
<td>16:8</td>
<td>7</td>
<td>542:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>80</td>
<td>539:9</td>
<td>548:2</td>
<td>+ 8:3</td>
<td></td>
</tr>
<tr>
<td>50:2</td>
<td>475:4</td>
<td>19:0</td>
<td>8</td>
<td>541:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>79</td>
<td>538:3</td>
<td>545:6</td>
<td>+ 7:3</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>469:6</td>
<td>21:9</td>
<td>5</td>
<td>534:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>79</td>
<td>531:6</td>
<td>542:8</td>
<td>+ 11:2</td>
<td></td>
</tr>
<tr>
<td>0 2</td>
<td>468:9</td>
<td>22:1</td>
<td>5</td>
<td>532:8</td>
<td>0:0007</td>
<td>..</td>
<td>..</td>
<td>78</td>
<td>530:2</td>
<td>530:1</td>
<td>+ 9:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>467:4</td>
<td>21:3</td>
<td>4</td>
<td>531:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>78</td>
<td>528:4</td>
<td>527:0</td>
<td>+ 8:6</td>
<td></td>
</tr>
<tr>
<td>1 2</td>
<td>465:2</td>
<td>20:0</td>
<td>3</td>
<td>526:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>78</td>
<td>525:6</td>
<td>524:1</td>
<td>+ 10:6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>465:3</td>
<td>20:0</td>
<td>3</td>
<td>525:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>77</td>
<td>523:8</td>
<td>521:2</td>
<td>+ 9:0</td>
<td></td>
</tr>
<tr>
<td>2 2</td>
<td>466:1</td>
<td>20:0</td>
<td>3</td>
<td>528:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>77</td>
<td>520:1</td>
<td>528:3</td>
<td>+ 2:2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>469:0</td>
<td>19:1</td>
<td>1</td>
<td>531:8</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>76</td>
<td>529:0</td>
<td>525:7</td>
<td>- 3:3</td>
<td></td>
</tr>
<tr>
<td>3 2</td>
<td>465:8</td>
<td>16:2</td>
<td>0</td>
<td>527:8</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>76</td>
<td>525:2</td>
<td>522:7</td>
<td>- 2:5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>463:8</td>
<td>15:7</td>
<td>0</td>
<td>525:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>75</td>
<td>522:6</td>
<td>519:9</td>
<td>- 2:7</td>
<td></td>
</tr>
<tr>
<td>7 0</td>
<td>440:1</td>
<td>27:3</td>
<td>55:5</td>
<td>496:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>70</td>
<td>494:4</td>
<td>500:2</td>
<td>+ 5:8</td>
<td></td>
</tr>
<tr>
<td>10 2</td>
<td>427:1</td>
<td>20:0</td>
<td>1</td>
<td>480:7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>69</td>
<td>478:3</td>
<td>478:9</td>
<td>+ 0:6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>428:9</td>
<td>22:2</td>
<td>1</td>
<td>482:5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>68</td>
<td>479:9</td>
<td>475:4</td>
<td>- 4:5</td>
<td></td>
</tr>
<tr>
<td>11 2</td>
<td>429:1</td>
<td>22:2</td>
<td>0</td>
<td>482:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>68</td>
<td>480:1</td>
<td>471:9</td>
<td>- 8:2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>431:2</td>
<td>21:7</td>
<td>52:9</td>
<td>494:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>68</td>
<td>482:2</td>
<td>468:1</td>
<td>- 14:1</td>
<td></td>
</tr>
<tr>
<td>17 2</td>
<td>389:3</td>
<td>39:2</td>
<td>2</td>
<td>435:2</td>
<td>0:0006</td>
<td>..</td>
<td>..</td>
<td>63</td>
<td>433:0</td>
<td>420:5</td>
<td>- 9:5</td>
<td></td>
</tr>
<tr>
<td>22 7</td>
<td>322:0</td>
<td>15:7</td>
<td>51:5</td>
<td>358:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>58</td>
<td>356:6</td>
<td>370:9</td>
<td>+ 14:3</td>
<td></td>
</tr>
<tr>
<td>23 2</td>
<td>320:2</td>
<td>15:2</td>
<td>4</td>
<td>356:0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>58</td>
<td>354:3</td>
<td>366:0</td>
<td>+ 11:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>317:2</td>
<td>15:5</td>
<td>3</td>
<td>352:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>57</td>
<td>351:0</td>
<td>361:1</td>
<td>+ 10:1</td>
<td></td>
</tr>
<tr>
<td>24 2</td>
<td>316:1</td>
<td>15:9</td>
<td>3</td>
<td>351:2</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>57</td>
<td>349:4</td>
<td>350:3</td>
<td>+ 6:9</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>311:8</td>
<td>16:2</td>
<td>2</td>
<td>346:2</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>56</td>
<td>344:5</td>
<td>351:1</td>
<td>+ 9:6</td>
<td></td>
</tr>
<tr>
<td>25 2</td>
<td>312:0</td>
<td>14:4</td>
<td>1</td>
<td>346:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>56</td>
<td>344:6</td>
<td>346:3</td>
<td>+ 1:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>313:2</td>
<td>13:5</td>
<td>1</td>
<td>347:4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>55</td>
<td>345:7</td>
<td>341:2</td>
<td>- 4:5</td>
<td></td>
</tr>
<tr>
<td>26 2</td>
<td>311:4</td>
<td>14:0</td>
<td>0</td>
<td>345:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>55</td>
<td>343:8</td>
<td>330:7</td>
<td>- 7:1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>306:0</td>
<td>15:9</td>
<td>0</td>
<td>339:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>54</td>
<td>337:5</td>
<td>332:0</td>
<td>- 5:5</td>
<td></td>
</tr>
<tr>
<td>27 2</td>
<td>303:5</td>
<td>18:1</td>
<td>60:9</td>
<td>336:2</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>53</td>
<td>334:7</td>
<td>327:1</td>
<td>- 7:6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>294:7</td>
<td>13:8</td>
<td>8</td>
<td>326:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>53</td>
<td>324:8</td>
<td>322:1</td>
<td>- 2:7</td>
<td></td>
</tr>
<tr>
<td>28 2</td>
<td>290:4</td>
<td>14:1</td>
<td>8</td>
<td>321:5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>53</td>
<td>320:1</td>
<td>317:5</td>
<td>- 2:6</td>
<td></td>
</tr>
<tr>
<td>29 2</td>
<td>283:9</td>
<td>11:7</td>
<td>6</td>
<td>314:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>314:5</td>
<td>308:0</td>
<td>303:1</td>
<td>- 5:9</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>279:1</td>
<td>12:0</td>
<td>6</td>
<td>308:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>308:6</td>
<td>301:0</td>
<td>303:1</td>
<td>- 5:9</td>
<td></td>
</tr>
<tr>
<td>I.</td>
<td>II.</td>
<td>III.</td>
<td>IV.</td>
<td>V</td>
<td>VI.</td>
<td>VII.</td>
<td>VIII.</td>
<td>IX.</td>
<td>X.</td>
<td>XI.</td>
<td>XII.</td>
<td>Remarks</td>
</tr>
<tr>
<td>-----</td>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>------</td>
<td>-------</td>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>Sidereal Time.</td>
<td>$G_0$</td>
<td>P. E.</td>
<td>$\sigma$</td>
<td>$G_0^*$</td>
<td>log $r^3$</td>
<td>log $R^3$</td>
<td>$e$</td>
<td>Sid. Time from Middle of Eclipse.</td>
<td>$G_0^*$</td>
<td>Curve</td>
<td>minus</td>
<td>Observ.</td>
</tr>
<tr>
<td>h.m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:30:2</td>
<td>271:5</td>
<td>± 10:9</td>
<td>50:5</td>
<td>300:0</td>
<td>0:0005</td>
<td>0:0005</td>
<td>*</td>
<td>1:45:3</td>
<td>300:4</td>
<td>298:5</td>
<td>-1:9</td>
<td></td>
</tr>
<tr>
<td>5:32:2</td>
<td>250:2</td>
<td>14:0</td>
<td>*3</td>
<td>282:7</td>
<td>*</td>
<td></td>
<td></td>
<td>46:8</td>
<td>283:0</td>
<td>284:3</td>
<td>+1:3</td>
<td></td>
</tr>
<tr>
<td>5:33:2</td>
<td>234:1</td>
<td>14:4</td>
<td>*2</td>
<td>290:3</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>280:6</td>
<td>279:0</td>
<td>-0:7</td>
<td></td>
</tr>
<tr>
<td>5:34:2</td>
<td>250:4</td>
<td>14:0</td>
<td>*2</td>
<td>276:1</td>
<td>*</td>
<td></td>
<td></td>
<td>45:8</td>
<td>276:4</td>
<td>275:0</td>
<td>-1:4</td>
<td></td>
</tr>
<tr>
<td>5:35:2</td>
<td>246:7</td>
<td>13:9</td>
<td>*1</td>
<td>270:8</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>271:1</td>
<td>270:8</td>
<td>-0:3</td>
<td></td>
</tr>
<tr>
<td>5:36:2</td>
<td>239:3</td>
<td>11:9</td>
<td>*0</td>
<td>263:6</td>
<td>*</td>
<td></td>
<td></td>
<td>44:8</td>
<td>263:9</td>
<td>265:9</td>
<td>+2:0</td>
<td></td>
</tr>
<tr>
<td>5:37:2</td>
<td>232:7</td>
<td>11:4</td>
<td>*0</td>
<td>256:3</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>256:5</td>
<td>261:0</td>
<td>+5:1</td>
<td></td>
</tr>
<tr>
<td>5:40:2</td>
<td>221:5</td>
<td>13:1</td>
<td>*5</td>
<td>244:0</td>
<td>*</td>
<td></td>
<td></td>
<td>42:8</td>
<td>244:2</td>
<td>247:6</td>
<td>+3:4</td>
<td></td>
</tr>
<tr>
<td>5:41:2</td>
<td>255:4</td>
<td>9:3</td>
<td>*4</td>
<td>235:4</td>
<td>*</td>
<td></td>
<td></td>
<td>40:0</td>
<td>225:7</td>
<td>221:2</td>
<td>-4:5</td>
<td></td>
</tr>
<tr>
<td>5:44:2</td>
<td>181:9</td>
<td>14:1</td>
<td>*0</td>
<td>199:0</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>199:2</td>
<td>197:1</td>
<td>-12:1</td>
<td></td>
</tr>
<tr>
<td>5:46:2</td>
<td>170:8</td>
<td>10:5</td>
<td>*8</td>
<td>186:7</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>186:9</td>
<td>173:2</td>
<td>-8:7</td>
<td></td>
</tr>
<tr>
<td>5:47:2</td>
<td>160:5</td>
<td>15:3</td>
<td>*8</td>
<td>182:0</td>
<td>*</td>
<td></td>
<td></td>
<td>34:8</td>
<td>182:2</td>
<td>173:9</td>
<td>-8:3</td>
<td></td>
</tr>
<tr>
<td>5:49:2</td>
<td>149:8</td>
<td>12:1</td>
<td>*7</td>
<td>162:6</td>
<td>*</td>
<td></td>
<td></td>
<td>33:8</td>
<td>163:8</td>
<td>165:0</td>
<td>+1:2</td>
<td></td>
</tr>
<tr>
<td>6:1:2</td>
<td>138:2</td>
<td>15:8</td>
<td>*5</td>
<td>150:8</td>
<td>*</td>
<td></td>
<td></td>
<td>32:8</td>
<td>151:0</td>
<td>156:4</td>
<td>+5:4</td>
<td></td>
</tr>
<tr>
<td>6:2:2</td>
<td>132:9</td>
<td>14:4</td>
<td>*5</td>
<td>145:0</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>145:1</td>
<td>152:2</td>
<td>+7:1</td>
<td></td>
</tr>
<tr>
<td>6:3:2</td>
<td>123:8</td>
<td>30:5</td>
<td>47:5</td>
<td>94:1</td>
<td>*</td>
<td></td>
<td></td>
<td>24:3</td>
<td>94:2</td>
<td>92:2</td>
<td>-2:0</td>
<td></td>
</tr>
<tr>
<td>7:0:2</td>
<td>37:5</td>
<td>10:6</td>
<td>*4</td>
<td>40:4</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>40:4</td>
<td>40:2</td>
<td>+5:8</td>
<td></td>
</tr>
<tr>
<td>7:1:2</td>
<td>36:6</td>
<td>10:3</td>
<td>*3</td>
<td>39:4</td>
<td>*</td>
<td></td>
<td></td>
<td>14:8</td>
<td>39:5</td>
<td>45:6</td>
<td>+6:1</td>
<td></td>
</tr>
<tr>
<td>7:2:2</td>
<td>38:6</td>
<td>10:6</td>
<td>*3</td>
<td>41:6</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>41:6</td>
<td>44:2</td>
<td>+2:6</td>
<td></td>
</tr>
<tr>
<td>7:4:2</td>
<td>48:7</td>
<td>9:0</td>
<td>*2</td>
<td>47:0</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>47:1</td>
<td>42:0</td>
<td>-5:1</td>
<td></td>
</tr>
<tr>
<td>7:6:2</td>
<td>42:1</td>
<td>10:2</td>
<td>*0</td>
<td>45:3</td>
<td>*</td>
<td></td>
<td></td>
<td>3</td>
<td>45:3</td>
<td>39:9</td>
<td>-5:4</td>
<td></td>
</tr>
<tr>
<td>I.</td>
<td>II.</td>
<td>III.</td>
<td>IV.</td>
<td>V.</td>
<td>VI.</td>
<td>VII.</td>
<td>VIII.</td>
<td>IX.</td>
<td>X.</td>
<td>XI.</td>
<td>XII.</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>-------</td>
<td>----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>Sideral Time</td>
<td>$G_1$</td>
<td>P. E.</td>
<td>$\alpha$</td>
<td>$G_2$</td>
<td>$\log \rho$</td>
<td>$\log K^2$</td>
<td>$\epsilon$</td>
<td>Sid. Time from Middle of Eclipse</td>
<td>$G_3^*$</td>
<td>Curve minus Observ.</td>
<td>Remarks</td>
<td></td>
</tr>
<tr>
<td>h m</td>
<td>30:5 &amp; $\pm$ 10:1 &amp; 45:9 &amp; 39:2 &amp; 0:0002 &amp; 0:0000 &amp; $-$ 11:3</td>
<td>39:2</td>
<td>37:9</td>
<td>$-$ 1:3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:7</td>
<td>23:4 &amp; 9:4 &amp; 9 &amp; 35:9 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; 10:8</td>
<td>35:9</td>
<td>37:9</td>
<td>$+$ 1:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:2</td>
<td>30:2 &amp; 10:0 &amp; 8 &amp; 32:4 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>32:5</td>
<td>30:1</td>
<td>$+$ 3:6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>27:4 &amp; 8:9 &amp; 7 &amp; 29:4 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>29:4</td>
<td>35:3</td>
<td>$+$ 5:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:2</td>
<td>28:6 &amp; 12:5 &amp; 7 &amp; 30:7 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>30:7</td>
<td>34:6</td>
<td>$+$ 3:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>25:8 &amp; 10:4 &amp; 6 &amp; 27:7 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>27:7</td>
<td>33:9</td>
<td>$+$ 6:2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:2</td>
<td>26:2 &amp; 10:5 &amp; 6 &amp; 28:1 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>28:1</td>
<td>33:1</td>
<td>$+$ 5:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>30:5 &amp; 11:3 &amp; 5 &amp; 32:7 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>32:7</td>
<td>32:6</td>
<td>$-$ 0:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:2</td>
<td>33:5 &amp; 12:0 &amp; 4 &amp; 35:9 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>35:9</td>
<td>31:9</td>
<td>$-$ 4:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>30:8 &amp; 13:1 &amp; 4 &amp; 33:0 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>33:0</td>
<td>31:3</td>
<td>$-$ 1:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:2</td>
<td>32:0 &amp; 13:9 &amp; 3 &amp; 34:3 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>34:3</td>
<td>30:9</td>
<td>$-$ 3:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>34:8 &amp; 12:9 &amp; 3 &amp; 37:3 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>37:3</td>
<td>30:4</td>
<td>$-$ 6:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:2</td>
<td>34:9 &amp; 13:4 &amp; 2 &amp; 37:4 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>37:4</td>
<td>30:0</td>
<td>$-$ 7:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19:2</td>
<td>24:8 &amp; 11:1 &amp; 44:5 &amp; 26:5 &amp; 0:0001 &amp; $\ldots$ &amp; $\ldots$</td>
<td>0:59:3</td>
<td>26:5</td>
<td>26:0</td>
<td>$-$ 0:5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24:2</td>
<td>20:2 &amp; 0:5 &amp; 0 &amp; 21:5 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>21:5</td>
<td>24:9</td>
<td>$+$ 3:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48:2</td>
<td>0:6 &amp; 7:6 &amp; 41:5 &amp; 0:6 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>39:3</td>
<td>0:6</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>0:9 &amp; 7:9 &amp; 4 &amp; 0:9 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>29:8</td>
<td>0:9</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:49:2</td>
<td>$-$ 1:1 &amp; 7:1 &amp; 4 &amp; 1:2 &amp; 0:0000 &amp; $\ldots$ &amp; $\ldots$</td>
<td>$-$ 0:3</td>
<td>1:2</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:17</td>
<td>$+$ 6:6 &amp; 16:6 &amp; 36:2 &amp; $+$ 6:7 &amp; 9:9995 &amp; $\ldots$ &amp; $\ldots$</td>
<td>$+$ 0:43:2</td>
<td>$+$ 6:7</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2:2</td>
<td>1:9 &amp; 11:1 &amp; 2 &amp; 2:0 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>2:0</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>2:8 &amp; 11:4 &amp; 2 &amp; 2:9 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>44:2</td>
<td>2:9</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:2</td>
<td>4:7 &amp; 10:0 &amp; 1 &amp; 4:8 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>4:8</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>7:3 &amp; 8:8 &amp; 1 &amp; 7:5 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>45:2</td>
<td>7:5</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:2</td>
<td>4:1 &amp; 4:9 &amp; 1 &amp; 4:2 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>4:2</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>3:6 &amp; 5:2 &amp; 1 &amp; 4:8 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>45:2</td>
<td>4:8</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:2</td>
<td>3:0 &amp; 5:4 &amp; 0 &amp; 3:1 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>3:1</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>4:1 &amp; 4:6 &amp; 0 &amp; 4:2 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>47:2</td>
<td>4:2</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:2</td>
<td>3:2 &amp; 4:4 &amp; 0 &amp; 3:3 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>3:3</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>4:5 &amp; 5:2 &amp; 0 &amp; 4:6 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>48:2</td>
<td>4:6</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>3:1 &amp; 4:2 &amp; 0 &amp; 3:2 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>3:2</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>2:7 &amp; 5:1 &amp; 0 &amp; 2:8 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>49:2</td>
<td>2:8</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:2</td>
<td>6:2 &amp; 7:6 &amp; 35:9 &amp; 6:4 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>6:4</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>10:1 &amp; 11:9 &amp; 9 &amp; 10:7 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>50:2</td>
<td>10:7</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:2</td>
<td>8:2 &amp; 12:9 &amp; 9 &amp; 8:4 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>7</td>
<td>8:4</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>12:6 &amp; 9:7 &amp; 7:4 &amp; $\ldots$ &amp; $\ldots$ &amp; $\ldots$</td>
<td>51:2</td>
<td>7:4</td>
<td>$\ldots$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Boeddicke—On Lunar Radiant Heat. 491

No observations from 6th 15:7 to 22:7. 5 Differences before and 5 after the interruption. Mean of six Differences only. 6th 48:2 till 8th 30:2. These values are very doubtful, since the moon's heat was not fully concentrated on the thermopiles (see page 485).
<table>
<thead>
<tr>
<th>I. Sideral Time.</th>
<th>II. G.</th>
<th>III. P. E.</th>
<th>IV. z.</th>
<th>V. G.</th>
<th>VI. log μ</th>
<th>VII. log R²</th>
<th>VIII. v.</th>
<th>IX. Sid. Time from Middle of Eclipses</th>
<th>X. G. *</th>
<th>XI. G. * Curve</th>
<th>XII. Curve minus Observ</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>h</td>
<td>m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>10:2</td>
<td>8:1 ± 13:3</td>
<td>35:9</td>
<td>8:3</td>
<td>9:9995</td>
<td>0:0000</td>
<td>0:51:7</td>
<td>8:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:2</td>
<td>8:5</td>
<td>13:3</td>
<td>3:8</td>
<td>8:8</td>
<td></td>
<td></td>
<td></td>
<td>7:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:2</td>
<td>4:1</td>
<td>14:5</td>
<td>3:8</td>
<td>4:2</td>
<td></td>
<td></td>
<td></td>
<td>7:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32:2</td>
<td>14:4</td>
<td>11:9</td>
<td>4:4</td>
<td>14:8</td>
<td></td>
<td></td>
<td></td>
<td>14:8</td>
<td>13:7</td>
<td>1:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32:2</td>
<td>16:3</td>
<td>11:9</td>
<td>4:4</td>
<td>17:6</td>
<td></td>
<td></td>
<td></td>
<td>17:6</td>
<td>14:9</td>
<td>2:7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>33:2</td>
<td>16:1</td>
<td>9:3</td>
<td>3:3</td>
<td>16:6</td>
<td></td>
<td></td>
<td></td>
<td>16:6</td>
<td>16:1</td>
<td>0:7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>34:2</td>
<td>15:8</td>
<td>9:4</td>
<td>3:3</td>
<td>16:3</td>
<td></td>
<td></td>
<td></td>
<td>16:3</td>
<td>16:5</td>
<td>1:1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35:2</td>
<td>17:8</td>
<td>9:4</td>
<td>3:3</td>
<td>18:3</td>
<td></td>
<td></td>
<td></td>
<td>18:3</td>
<td>20:8</td>
<td>2:5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36:2</td>
<td>21:5</td>
<td>6:4</td>
<td>3:3</td>
<td>22:1</td>
<td></td>
<td></td>
<td></td>
<td>22:1</td>
<td>22:5</td>
<td>0:4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38:2</td>
<td>23:7</td>
<td>7:1</td>
<td>3:3</td>
<td>24:4</td>
<td></td>
<td></td>
<td></td>
<td>24:4</td>
<td>26:1</td>
<td>1:8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39:2</td>
<td>29:4</td>
<td>12:8</td>
<td>3:3</td>
<td>30:2</td>
<td></td>
<td></td>
<td></td>
<td>30:2</td>
<td>30:0</td>
<td>0:2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>37:2</td>
<td>37:3</td>
<td>14:9</td>
<td>3:3</td>
<td>33:3</td>
<td></td>
<td></td>
<td></td>
<td>33:3</td>
<td>32:0</td>
<td>6:3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38:2</td>
<td>44:0</td>
<td>16:3</td>
<td>3:3</td>
<td>45:2</td>
<td></td>
<td></td>
<td></td>
<td>45:2</td>
<td>33:9</td>
<td>11:3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38:2</td>
<td>43:8</td>
<td>16:4</td>
<td>3:3</td>
<td>45:6</td>
<td></td>
<td></td>
<td></td>
<td>45:6</td>
<td>44:9</td>
<td>8:9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>39:2</td>
<td>49:9</td>
<td>16:9</td>
<td>3:3</td>
<td>45:1</td>
<td></td>
<td></td>
<td></td>
<td>45:1</td>
<td>38:1</td>
<td>7:0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40:2</td>
<td>48:5</td>
<td>19:6</td>
<td>3:3</td>
<td>48:8</td>
<td></td>
<td></td>
<td></td>
<td>48:8</td>
<td>47:2</td>
<td>2:8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41:2</td>
<td>57:7</td>
<td>21:7</td>
<td>3:3</td>
<td>59:3</td>
<td></td>
<td></td>
<td></td>
<td>59:3</td>
<td>59:2</td>
<td>9:3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41:2</td>
<td>50:8</td>
<td>22:5</td>
<td>3:3</td>
<td>61:5</td>
<td></td>
<td></td>
<td></td>
<td>61:5</td>
<td>52:2</td>
<td>9:2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41:2</td>
<td>59:5</td>
<td>22:2</td>
<td>3:3</td>
<td>61:2</td>
<td></td>
<td></td>
<td></td>
<td>61:2</td>
<td>61:1</td>
<td>6:2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44:2</td>
<td>78:6</td>
<td>10:2</td>
<td>3:3</td>
<td>80:8</td>
<td></td>
<td></td>
<td></td>
<td>80:8</td>
<td>70:6</td>
<td>10:0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I.</td>
<td>II.</td>
<td>III.</td>
<td>IV.</td>
<td>V.</td>
<td>VI.</td>
<td>VII.</td>
<td>VIII.</td>
<td>IX.</td>
<td>X.</td>
<td>XI.</td>
<td>XII.</td>
<td>Remarks</td>
</tr>
<tr>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>-------</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>Sidereal Time.</td>
<td>G.</td>
<td>P. E.</td>
<td>φ</td>
<td>Gₚ</td>
<td>log φ²</td>
<td>log R²</td>
<td>e</td>
<td>Gₚ*</td>
<td>Gₚ* Curve</td>
<td>minus Obsrv.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>h m</td>
<td>79:1</td>
<td>9:8</td>
<td>35:3</td>
<td>81:3</td>
<td>9-9993</td>
<td>0:0000</td>
<td>1+</td>
<td>26:7</td>
<td>81:2</td>
<td>73:4</td>
<td>- 7:8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>75:2</td>
<td>7:6</td>
<td>2</td>
<td>77:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>27:2</td>
<td>77:1</td>
<td>70:1</td>
<td>- 1:0</td>
<td></td>
</tr>
<tr>
<td>.2</td>
<td>75:7</td>
<td>8:1</td>
<td>2</td>
<td>77:8</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>77:7</td>
<td>78:9</td>
<td>+ 1:2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>74:8</td>
<td>7:8</td>
<td>2</td>
<td>76:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>28:2</td>
<td>76:7</td>
<td>81:9</td>
<td>+ 5:2</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>70:2</td>
<td>9:4</td>
<td>2</td>
<td>81:4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>81:3</td>
<td>84:9</td>
<td>+ 3:6</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>82:6</td>
<td>9:5</td>
<td>2</td>
<td>85:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>29:2</td>
<td>85:8</td>
<td>87:9</td>
<td>+ 2:1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>85:6</td>
<td>13:1</td>
<td>3</td>
<td>88:0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>87:8</td>
<td>90:8</td>
<td>+ 3:0</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>85:0</td>
<td>12:0</td>
<td>3</td>
<td>87:4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>30:2</td>
<td>87:2</td>
<td>93:8</td>
<td>+ 6:6</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>88:9</td>
<td>11:7</td>
<td>3</td>
<td>91:4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>91:2</td>
<td>96:8</td>
<td>+ 5:6</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>94:4</td>
<td>12:6</td>
<td>3</td>
<td>87:0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>31:2</td>
<td>96:9</td>
<td>99:9</td>
<td>+ 3:0</td>
<td></td>
</tr>
<tr>
<td>50:2</td>
<td>101:0</td>
<td>12:9</td>
<td>3</td>
<td>103:8</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>103:6</td>
<td>102:9</td>
<td>- 0:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>110:6</td>
<td>16:8</td>
<td>3</td>
<td>113:7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>32:2</td>
<td>113:4</td>
<td>106:0</td>
<td>+ 2:6</td>
<td></td>
</tr>
<tr>
<td>51:2</td>
<td>120:5</td>
<td>22:6</td>
<td>3</td>
<td>123:8</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>123:6</td>
<td>100:1</td>
<td>- 14:5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>131:4</td>
<td>23:9</td>
<td>3</td>
<td>135:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>33:2</td>
<td>134:8</td>
<td>112:3</td>
<td>- 22:5</td>
<td></td>
</tr>
<tr>
<td>52:2</td>
<td>137:6</td>
<td>24:3</td>
<td>3</td>
<td>141:5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>141:2</td>
<td>115:3</td>
<td>- 25:9</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>141:8</td>
<td>24:3</td>
<td>3</td>
<td>145:7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>34:2</td>
<td>145:5</td>
<td>118:4</td>
<td>- 27:1</td>
<td></td>
</tr>
<tr>
<td>53:2</td>
<td>145:5</td>
<td>23:1</td>
<td>3</td>
<td>149:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>149:3</td>
<td>121:8</td>
<td>- 27:5</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>147:5</td>
<td>21:0</td>
<td>3</td>
<td>151:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>35:2</td>
<td>151:4</td>
<td>125:0</td>
<td>- 26:4</td>
<td></td>
</tr>
<tr>
<td>54:2</td>
<td>149:2</td>
<td>19:3</td>
<td>3</td>
<td>155:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>153:1</td>
<td>128:6</td>
<td>- 24:6</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>155:1</td>
<td>19:6</td>
<td>3</td>
<td>159:4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>36:2</td>
<td>159:2</td>
<td>131:9</td>
<td>- 27:3</td>
<td></td>
</tr>
<tr>
<td>55:2</td>
<td>155:9</td>
<td>10:2</td>
<td>3</td>
<td>160:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>160:0</td>
<td>155:4</td>
<td>- 19:6</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>152:8</td>
<td>19:5</td>
<td>3</td>
<td>157:0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>37:2</td>
<td>158:6</td>
<td>139:0</td>
<td>- 13:8</td>
<td></td>
</tr>
<tr>
<td>56:2</td>
<td>148:3</td>
<td>17:4</td>
<td>3</td>
<td>152:4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>152:2</td>
<td>142:2</td>
<td>- 10:0</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>146:6</td>
<td>16:0</td>
<td>3</td>
<td>150:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>38:2</td>
<td>159:5</td>
<td>143:0</td>
<td>- 9:6</td>
<td></td>
</tr>
<tr>
<td>57:2</td>
<td>146:5</td>
<td>15:4</td>
<td>3</td>
<td>149:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>149:4</td>
<td>148:4</td>
<td>0:0</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>147:2</td>
<td>16:5</td>
<td>3</td>
<td>151:3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>39:2</td>
<td>151:1</td>
<td>152:0</td>
<td>+ 1:9</td>
<td></td>
</tr>
<tr>
<td>58:2</td>
<td>151:5</td>
<td>18:4</td>
<td>3</td>
<td>155:7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>155:5</td>
<td>156:8</td>
<td>+ 1:3</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>158:8</td>
<td>15:3</td>
<td>4</td>
<td>163:2</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>40:2</td>
<td>163:0</td>
<td>160:2</td>
<td>- 2:8</td>
<td></td>
</tr>
<tr>
<td>59:2</td>
<td>159:5</td>
<td>12:5</td>
<td>4</td>
<td>170:6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>170:3</td>
<td>164:1</td>
<td>- 6:2</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>163:1</td>
<td>12:2</td>
<td>4</td>
<td>169:7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>41:2</td>
<td>169:4</td>
<td>168:0</td>
<td>- 1:4</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>171:4</td>
<td>11:7</td>
<td>4</td>
<td>176:2</td>
<td>9-9992</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>175:9</td>
<td>171:9</td>
<td>- 4:0</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>175:0</td>
<td>9:9</td>
<td>4</td>
<td>179:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>42:2</td>
<td>179:6</td>
<td>175:8</td>
<td>- 3:8</td>
<td></td>
</tr>
<tr>
<td>1:2</td>
<td>178:1</td>
<td>7:6</td>
<td>4</td>
<td>183:1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>182:7</td>
<td>179:4</td>
<td>- 3:3</td>
<td></td>
</tr>
<tr>
<td>.7</td>
<td>179:8</td>
<td>7:5</td>
<td>4</td>
<td>184:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>43:2</td>
<td>184:6</td>
<td>183:5</td>
<td>- 1:1</td>
<td></td>
</tr>
<tr>
<td>2:2</td>
<td>186:6</td>
<td>10:2</td>
<td>4</td>
<td>191:9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>.7</td>
<td>191:5</td>
<td>187:3</td>
<td>- 4:2</td>
<td></td>
</tr>
<tr>
<td>I. Sidereal Time</td>
<td>II. G.</td>
<td>III. P. E.</td>
<td>IV. z.</td>
<td>V. G&lt;sub&gt;e&lt;/sub&gt;</td>
<td>VI. log ρ&lt;sub&gt;∞&lt;/sub&gt;</td>
<td>VII. log R&lt;sub&gt;∞&lt;/sub&gt;</td>
<td>VIII. t.&lt;sub&gt;∞&lt;/sub&gt;</td>
<td>IX. Sid. Time from Middle of Eclipse</td>
<td>X. G&lt;sub&gt;∞&lt;/sub&gt;</td>
<td>XI. Curve minus Obs.</td>
<td>XII. Remarks</td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>-------</td>
<td>-----------</td>
<td>------</td>
<td>------------</td>
<td>----------------</td>
<td>----------------</td>
<td>--------</td>
<td>-------------------------------</td>
<td>----------------</td>
<td>-----------------</td>
<td>----------------</td>
<td></td>
</tr>
<tr>
<td>h = 9 2:7</td>
<td>191:6</td>
<td>± 12:8</td>
<td>35:4</td>
<td>197:0</td>
<td>9-9992</td>
<td>0-0000</td>
<td>+ 1 44:2</td>
<td>196:6 191:2 - 5:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3:2</td>
<td>194:4</td>
<td>13:1</td>
<td>4</td>
<td>199:9</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>199:5 195:4 - 4:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>192:6</td>
<td>14:9</td>
<td>4</td>
<td>197:9</td>
<td>...</td>
<td>...</td>
<td>45:2</td>
<td>197:5 199:2 + 1:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4:2</td>
<td>191:4</td>
<td>16:6</td>
<td>4</td>
<td>196:8</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>196:4 203:3 + 6:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>194:2</td>
<td>14:4</td>
<td>5</td>
<td>199:6</td>
<td>...</td>
<td>...</td>
<td>46:2</td>
<td>199:3 207:8 + 8:5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5:2</td>
<td>194:2</td>
<td>14:4</td>
<td>5</td>
<td>199:8</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>199:5 211:8 + 12:3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>194:4</td>
<td>14:9</td>
<td>5</td>
<td>199:9</td>
<td>...</td>
<td>...</td>
<td>47:2</td>
<td>199:5 216:0 + 16:6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6:2</td>
<td>191:9</td>
<td>17:3</td>
<td>5</td>
<td>197:3</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>197:0 220:2 + 22:2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>191:0</td>
<td>17:5</td>
<td>5</td>
<td>195:4</td>
<td>...</td>
<td>...</td>
<td>48:2</td>
<td>195:1 224:9 + 29:8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7:2</td>
<td>190:0</td>
<td>16:7</td>
<td>5</td>
<td>195:4</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>195:1 228:9 + 33:8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>184:4</td>
<td>14:8</td>
<td>5</td>
<td>190:6</td>
<td>...</td>
<td>...</td>
<td>49:2</td>
<td>189:2 232:3 + 44:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:2</td>
<td>181:1</td>
<td>13:0</td>
<td>5</td>
<td>185:2</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>185:9 237:3 + 51:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>191:8</td>
<td>20:3</td>
<td>5</td>
<td>197:2</td>
<td>...</td>
<td>...</td>
<td>30:0</td>
<td>198:5 242:2 + 43:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:2</td>
<td>208:1</td>
<td>20:3</td>
<td>5</td>
<td>208:8</td>
<td>...</td>
<td>...</td>
<td>-7</td>
<td>210:1 247:0 + 36:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>211:1</td>
<td>32:0</td>
<td>6</td>
<td>217:2</td>
<td>...</td>
<td>...</td>
<td>-31</td>
<td>213:8 251:9 + 33:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:2</td>
<td>216:2</td>
<td>33:9</td>
<td>6</td>
<td>222:4</td>
<td>...</td>
<td>...</td>
<td>-31</td>
<td>223:8 256:9 + 33:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>225:4</td>
<td>53:1</td>
<td>6</td>
<td>231:9</td>
<td>...</td>
<td>...</td>
<td>-32</td>
<td>232:9 261:9 + 28:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11:2</td>
<td>240:9</td>
<td>32:6</td>
<td>6</td>
<td>247:8</td>
<td>...</td>
<td>...</td>
<td>-32</td>
<td>243:3 266:6 + 17:3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>255:4</td>
<td>32:6</td>
<td>6</td>
<td>262:8</td>
<td>...</td>
<td>...</td>
<td>-32</td>
<td>253:2 264:3 + 17:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12:2</td>
<td>261:5</td>
<td>31:4</td>
<td>6</td>
<td>259:0</td>
<td>...</td>
<td>...</td>
<td>-33</td>
<td>270:7 276:7 + 6:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>278:4</td>
<td>24:2</td>
<td>6</td>
<td>281:3</td>
<td>...</td>
<td>...</td>
<td>-33</td>
<td>283:0 282:0 - 1:0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:2</td>
<td>284:9</td>
<td>13:4</td>
<td>6</td>
<td>233:2</td>
<td>...</td>
<td>...</td>
<td>-34</td>
<td>284:9 287:4 - 7:5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>290:6</td>
<td>14:5</td>
<td>7</td>
<td>299:0</td>
<td>...</td>
<td>...</td>
<td>-34</td>
<td>299:0 292:9 - 7:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14:2</td>
<td>294:3</td>
<td>15:9</td>
<td>7</td>
<td>302:8</td>
<td>...</td>
<td>...</td>
<td>-35</td>
<td>304:7 298:1 - 6:6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>297:3</td>
<td>16:2</td>
<td>7</td>
<td>306:0</td>
<td>...</td>
<td>...</td>
<td>-35</td>
<td>307:9 303:3 - 4:6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15:2</td>
<td>305:5</td>
<td>15:5</td>
<td>7</td>
<td>314:5</td>
<td>9-9991</td>
<td>-36</td>
<td>316:3 308:8 - 7:5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>312:7</td>
<td>12:3</td>
<td>7</td>
<td>321:9</td>
<td>...</td>
<td>...</td>
<td>-37</td>
<td>314:1 323:8 - 9:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20:7</td>
<td>372:6</td>
<td>31:3</td>
<td>8</td>
<td>333:5</td>
<td>...</td>
<td>...</td>
<td>-42</td>
<td>386:9 360:9 - 19:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25:0</td>
<td>415:8</td>
<td>8:5</td>
<td>30:0</td>
<td>423:3</td>
<td>...</td>
<td>...</td>
<td>-43</td>
<td>431:0 408:9 - 22:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27:2</td>
<td>414:2</td>
<td>11:9</td>
<td>-1</td>
<td>426:8</td>
<td>...</td>
<td>...</td>
<td>-47</td>
<td>429:9 427:0 - 2:6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30:2</td>
<td>423:7</td>
<td>13:7</td>
<td>-2</td>
<td>436:7</td>
<td>...</td>
<td>...</td>
<td>-50</td>
<td>439:6 443:3 + 8:7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>428:0</td>
<td>13:4</td>
<td>-2</td>
<td>441:3</td>
<td>...</td>
<td>...</td>
<td>-50</td>
<td>442:2 451:6 + 7:4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31:2</td>
<td>437:3</td>
<td>8:2</td>
<td>-3</td>
<td>450:9</td>
<td>...</td>
<td>...</td>
<td>-51</td>
<td>453:9 454:7 + 0:8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>438:8</td>
<td>7:4</td>
<td>-3</td>
<td>452:5</td>
<td>...</td>
<td>...</td>
<td>-52</td>
<td>455:5 457:4 + 1:9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32:2</td>
<td>437:6</td>
<td>8:5</td>
<td>-3</td>
<td>451:1</td>
<td>...</td>
<td>...</td>
<td>-52</td>
<td>454:1 460:2 + 6:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From 9h 7:7m till 9h 9:2m the rays of the moon were not quite concentrated on the pile, so that the values G from 9h 6:2m till 11:2m (both extremes included) are somewhat too small.
<table>
<thead>
<tr>
<th>I. Sidereal Time</th>
<th>II. G.</th>
<th>III. P. E.</th>
<th>IV. z.</th>
<th>V. G_m</th>
<th>VI. log ρ_m</th>
<th>VII. log R_m</th>
<th>VIII. α &amp; 39;</th>
<th>IX. Sid. Time from Middle of Eclipse</th>
<th>X. G_m*</th>
<th>XI. G_m* Curve</th>
<th>XII. Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>h m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 52:7</td>
<td>439:5</td>
<td>±8:0</td>
<td>±30:3</td>
<td>453:3</td>
<td>9-9990</td>
<td>0-0000</td>
<td>±3:53</td>
<td>+2 /14:2</td>
<td>456:3</td>
<td>456:4</td>
<td>+7:1</td>
</tr>
<tr>
<td>34:2</td>
<td>439:1</td>
<td>8:3</td>
<td>±4:4</td>
<td>452:9</td>
<td></td>
<td></td>
<td>±5:53</td>
<td>15:2:455:9</td>
<td>469:0</td>
<td>+13:1</td>
<td></td>
</tr>
<tr>
<td>34:2</td>
<td>439:0</td>
<td>8:4</td>
<td>±4:4</td>
<td>452:8</td>
<td></td>
<td></td>
<td>±5:54</td>
<td>±7:455:8</td>
<td>471:7</td>
<td>+15:9</td>
<td></td>
</tr>
<tr>
<td>35:2</td>
<td>444:3</td>
<td>14:8</td>
<td>±5:4</td>
<td>458:3</td>
<td></td>
<td></td>
<td>±5:55</td>
<td>16:2:456:0</td>
<td>474:3</td>
<td>+18:3</td>
<td></td>
</tr>
<tr>
<td>36:2</td>
<td>455:1</td>
<td>21:3</td>
<td>±5:4</td>
<td>469:6</td>
<td></td>
<td></td>
<td>±5:7</td>
<td>18:2:472:0</td>
<td>484:3</td>
<td>+2:3</td>
<td></td>
</tr>
<tr>
<td>46:2</td>
<td>510:7</td>
<td>7:1</td>
<td>±0:0</td>
<td>528:1</td>
<td></td>
<td></td>
<td>±6:65</td>
<td>30:2:532:0</td>
<td>514:9</td>
<td>-17:1</td>
<td></td>
</tr>
<tr>
<td>47:2</td>
<td>510:0</td>
<td>7:7</td>
<td>±1:0</td>
<td>527:2</td>
<td></td>
<td></td>
<td>±6:67</td>
<td>28:2:531:3</td>
<td>517:0</td>
<td>-14:3</td>
<td></td>
</tr>
<tr>
<td>47:2</td>
<td>509:0</td>
<td>8:3</td>
<td>±1:0</td>
<td>520:1</td>
<td></td>
<td></td>
<td>±6:67</td>
<td>29:2:530:2</td>
<td>518:0</td>
<td>-12:2</td>
<td></td>
</tr>
</tbody>
</table>

No observations from 9h 50:7' to 52:2'. 5 Differences before and 5 after the interruption.
<table>
<thead>
<tr>
<th>I. Sideral Time</th>
<th>II. G.</th>
<th>III. F. E.</th>
<th>IV. z.</th>
<th>V. G&lt;sub&gt;λ&lt;/sub&gt;</th>
<th>VI. log ρ&lt;sup&gt;2&lt;/sup&gt;</th>
<th>VII. log R&lt;sup&gt;2&lt;/sup&gt;</th>
<th>VIII. ε.</th>
<th>IX. Sid. Time from Middle of Eclipse</th>
<th>X. G&lt;sub&gt;λ&lt;/sub&gt;&lt;sup&gt;*&lt;/sup&gt;</th>
<th>XI. Curve minus Observ.</th>
<th>XII. Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>50:2</td>
<td>506:3</td>
<td>± 10:0</td>
<td>3:6</td>
<td>524:6</td>
<td></td>
<td></td>
<td>7:6</td>
<td>7 528:8</td>
<td>527:9</td>
<td>- 0:9</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>504:7</td>
<td>± 10:1</td>
<td>7:7</td>
<td>522:0</td>
<td></td>
<td></td>
<td>77:7</td>
<td>7 527:1</td>
<td>528:1</td>
<td>+ 1:0</td>
<td></td>
</tr>
<tr>
<td>57:2</td>
<td>501:5</td>
<td>± 9:9</td>
<td>7:7</td>
<td>522:6</td>
<td></td>
<td></td>
<td>77:7</td>
<td>7 529:0</td>
<td>528:3</td>
<td>+ 1:4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>509:6</td>
<td>± 10:1</td>
<td>7:7</td>
<td>523:1</td>
<td></td>
<td></td>
<td>77:7</td>
<td>7 532:3</td>
<td>538:7</td>
<td>- 3:6</td>
<td></td>
</tr>
<tr>
<td>59:2</td>
<td>508:1</td>
<td>± 10:4</td>
<td>8:8</td>
<td>526:0</td>
<td></td>
<td></td>
<td>78:7</td>
<td>7 531:0</td>
<td>529:9</td>
<td>- 2:1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>506:2</td>
<td>± 9:3</td>
<td>8:8</td>
<td>524:8</td>
<td></td>
<td></td>
<td>78:7</td>
<td>7 532:3</td>
<td>529:3</td>
<td>- 3:9</td>
<td></td>
</tr>
<tr>
<td>59:2</td>
<td>510:4</td>
<td>± 10:7</td>
<td>8:8</td>
<td>528:3</td>
<td></td>
<td></td>
<td>79:7</td>
<td>7 533:2</td>
<td>529:4</td>
<td>- 7:5</td>
<td></td>
</tr>
<tr>
<td>10 0:2</td>
<td>515:3</td>
<td>± 8:4</td>
<td>9:9</td>
<td>534:2</td>
<td>9:9988</td>
<td></td>
<td>89:7</td>
<td>7 538:6</td>
<td>529:8</td>
<td>- 8:8</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>509:3</td>
<td>± 14:9</td>
<td>9:9</td>
<td>528:1</td>
<td></td>
<td></td>
<td>81:7</td>
<td>7 532:3</td>
<td>529:9</td>
<td>- 2:4</td>
<td></td>
</tr>
<tr>
<td>1:2</td>
<td>508:5</td>
<td>± 13:9</td>
<td>38:0</td>
<td>527:3</td>
<td></td>
<td></td>
<td>82:7</td>
<td>7 531:9</td>
<td>530:0</td>
<td>- 1:9</td>
<td></td>
</tr>
<tr>
<td>2:2</td>
<td>512:9</td>
<td>± 14:4</td>
<td>6:0</td>
<td>532:1</td>
<td></td>
<td></td>
<td>82:7</td>
<td>7 536:7</td>
<td>530:0</td>
<td>- 6:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>512:7</td>
<td>± 14:3</td>
<td>1:1</td>
<td>532:0</td>
<td></td>
<td></td>
<td>83:7</td>
<td>7 533:7</td>
<td>530:1</td>
<td>- 6:4</td>
<td></td>
</tr>
<tr>
<td>3:2</td>
<td>514:3</td>
<td>± 13:4</td>
<td>1:1</td>
<td>533:7</td>
<td></td>
<td></td>
<td>83:7</td>
<td>7 538:3</td>
<td>530:1</td>
<td>- 6:2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>516:5</td>
<td>± 14:3</td>
<td>2:2</td>
<td>535:9</td>
<td></td>
<td></td>
<td>84:7</td>
<td>7 540:5</td>
<td>530:2</td>
<td>- 10:3</td>
<td></td>
</tr>
<tr>
<td>4:2</td>
<td>516:2</td>
<td>± 14:1</td>
<td>2:2</td>
<td>535:7</td>
<td></td>
<td></td>
<td>85:7</td>
<td>7 540:3</td>
<td>530:2</td>
<td>- 10:1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>516:5</td>
<td>± 14:2</td>
<td>2:2</td>
<td>536:0</td>
<td></td>
<td></td>
<td>85:7</td>
<td>7 540:6</td>
<td>530:3</td>
<td>- 10:3</td>
<td></td>
</tr>
<tr>
<td>5:2</td>
<td>517:7</td>
<td>± 14:3</td>
<td>3:3</td>
<td>537:4</td>
<td></td>
<td></td>
<td>86:7</td>
<td>7 542:0</td>
<td>530:3</td>
<td>- 11:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>525:5</td>
<td>± 6:1</td>
<td>3:3</td>
<td>545:6</td>
<td></td>
<td></td>
<td>87:7</td>
<td>7 550:3</td>
<td>530:3</td>
<td>- 20:0</td>
<td></td>
</tr>
<tr>
<td>6:2</td>
<td>527:6</td>
<td>± 4:8</td>
<td>3:3</td>
<td>547:8</td>
<td></td>
<td></td>
<td>87:7</td>
<td>7 552:5</td>
<td>530:3</td>
<td>- 22:2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>529:1</td>
<td>± 4:7</td>
<td>4:4</td>
<td>549:5</td>
<td></td>
<td></td>
<td>87:7</td>
<td>7 554:3</td>
<td>530:3</td>
<td>- 24:0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>527:2</td>
<td>± 5:8</td>
<td>4:4</td>
<td>547:8</td>
<td></td>
<td></td>
<td>88:7</td>
<td>7 552:5</td>
<td>530:4</td>
<td>- 22:1</td>
<td></td>
</tr>
<tr>
<td>8:2</td>
<td>525:8</td>
<td>± 7:7</td>
<td>5:5</td>
<td>546:4</td>
<td></td>
<td></td>
<td>88:7</td>
<td>7 551:1</td>
<td>530:4</td>
<td>- 20:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>524:3</td>
<td>± 8:2</td>
<td>5:5</td>
<td>543:9</td>
<td></td>
<td></td>
<td>89:7</td>
<td>7 547:5</td>
<td>530:4</td>
<td>- 18:2</td>
<td></td>
</tr>
<tr>
<td>9:2</td>
<td>522:4</td>
<td>± 7:9</td>
<td>6:6</td>
<td>542:8</td>
<td></td>
<td></td>
<td>90:7</td>
<td>7 547:5</td>
<td>530:4</td>
<td>- 17:1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>525:8</td>
<td>± 10:2</td>
<td>6:6</td>
<td>546:7</td>
<td></td>
<td></td>
<td>90:7</td>
<td>7 551:4</td>
<td>530:4</td>
<td>- 21:0</td>
<td></td>
</tr>
<tr>
<td>16:2</td>
<td>526:5</td>
<td>± 10:3</td>
<td>6:6</td>
<td>547:3</td>
<td></td>
<td></td>
<td>91:7</td>
<td>7 552:1</td>
<td>530:4</td>
<td>- 21:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>526:4</td>
<td>± 10:2</td>
<td>7:7</td>
<td>547:3</td>
<td></td>
<td></td>
<td>92:7</td>
<td>7 552:1</td>
<td>530:4</td>
<td>- 21:7</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>524:1</td>
<td>± 10:1</td>
<td>7:7</td>
<td>545:3</td>
<td></td>
<td></td>
<td>92:7</td>
<td>7 550:0</td>
<td>530:5</td>
<td>- 19:5</td>
<td></td>
</tr>
<tr>
<td>12:2</td>
<td>524:3</td>
<td>± 10:0</td>
<td>8:8</td>
<td>545:3</td>
<td></td>
<td></td>
<td>93:7</td>
<td>7 550:0</td>
<td>530:5</td>
<td>- 19:5</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>528:7</td>
<td>± 11:4</td>
<td>8:8</td>
<td>550:0</td>
<td></td>
<td></td>
<td>93:7</td>
<td>7 554:9</td>
<td>530:5</td>
<td>- 14:4</td>
<td></td>
</tr>
<tr>
<td>J.</td>
<td>II.</td>
<td>III.</td>
<td>IV.</td>
<td>V.</td>
<td>VI.</td>
<td>VII.</td>
<td>VIII.</td>
<td>IX.</td>
<td>X.</td>
<td>XI.</td>
<td>XII.</td>
</tr>
<tr>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>------</td>
<td>-------</td>
<td>-----</td>
<td>----</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>Sidereal Time.</td>
<td>G.</td>
<td>P. E.</td>
<td>z.</td>
<td>G₀*</td>
<td>log p</td>
<td>log P²</td>
<td>c₀</td>
<td>h m</td>
<td>G₀*</td>
<td>Curve minus Observ.</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>m</td>
<td>h</td>
<td>m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>13-2</td>
<td>531.3</td>
<td>± 9.4</td>
<td>38-9</td>
<td>552.7</td>
<td>9-9988</td>
<td>0-0000</td>
<td>1-94</td>
<td>+ 2 54-7</td>
<td>557-6</td>
<td>530-6</td>
</tr>
<tr>
<td>-7</td>
<td>523-2</td>
<td>8.0</td>
<td>-0</td>
<td>551-9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-95</td>
<td>55-2</td>
<td>560-1</td>
<td>530-6</td>
</tr>
<tr>
<td>14-2</td>
<td>529-4</td>
<td>12-6</td>
<td>-9</td>
<td>550-9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-95</td>
<td>7</td>
<td>556-0</td>
<td>530-6</td>
</tr>
<tr>
<td>-7</td>
<td>521-2</td>
<td>15-8</td>
<td>39-0</td>
<td>542-5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-95</td>
<td>58-2</td>
<td>547-5</td>
<td>530-7</td>
</tr>
<tr>
<td>15-2</td>
<td>516-9</td>
<td>17-0</td>
<td>-0</td>
<td>538-0</td>
<td>9-9987</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>7</td>
<td>542-9</td>
<td>530-7</td>
</tr>
<tr>
<td>-7</td>
<td>512-6</td>
<td>16-7</td>
<td>-1</td>
<td>533-5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>57-2</td>
<td>534-4</td>
<td>530-8</td>
</tr>
<tr>
<td>16-2</td>
<td>511-6</td>
<td>16-5</td>
<td>-1</td>
<td>532-7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>7</td>
<td>537-5</td>
<td>530-8</td>
</tr>
<tr>
<td>-7</td>
<td>514-4</td>
<td>16-4</td>
<td>-2</td>
<td>530-6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>58-2</td>
<td>537-4</td>
<td>530-8</td>
</tr>
<tr>
<td>17-2</td>
<td>513-8</td>
<td>18-2</td>
<td>-2</td>
<td>533-2</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-98</td>
<td>7</td>
<td>540-1</td>
<td>530-8</td>
</tr>
<tr>
<td>-7</td>
<td>512-8</td>
<td>17-4</td>
<td>-2</td>
<td>534-3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-98</td>
<td>50-2</td>
<td>539-3</td>
<td>530-9</td>
</tr>
<tr>
<td>18-2</td>
<td>511-1</td>
<td>17-1</td>
<td>-3</td>
<td>533-0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-93</td>
<td>7</td>
<td>537-5</td>
<td>530-9</td>
</tr>
<tr>
<td>-7</td>
<td>509-0</td>
<td>18-8</td>
<td>-3</td>
<td>530-4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-99</td>
<td>3 0-2</td>
<td>535-6</td>
<td>530-9</td>
</tr>
<tr>
<td>19-2</td>
<td>508-4</td>
<td>17-2</td>
<td>-4</td>
<td>529-0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-99</td>
<td>7</td>
<td>535-0</td>
<td>530-9</td>
</tr>
<tr>
<td>-7</td>
<td>507-0</td>
<td>19-4</td>
<td>-4</td>
<td>525-5</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-91</td>
<td>1-2</td>
<td>533-5</td>
<td>530-9</td>
</tr>
<tr>
<td>20-2</td>
<td>506-1</td>
<td>19-1</td>
<td>-4</td>
<td>527-7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-92</td>
<td>7</td>
<td>532-7</td>
<td>530-9</td>
</tr>
<tr>
<td>-7</td>
<td>502-1</td>
<td>22-1</td>
<td>-5</td>
<td>523-0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-92</td>
<td>2-2</td>
<td>528-5</td>
<td>531-0</td>
</tr>
<tr>
<td>21-2</td>
<td>498-0</td>
<td>22-4</td>
<td>-5</td>
<td>519-4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-92</td>
<td>7</td>
<td>524-3</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>495-5</td>
<td>21-9</td>
<td>-6</td>
<td>516-9</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-93</td>
<td>3 0-2</td>
<td>521-9</td>
<td>531-0</td>
</tr>
<tr>
<td>22-2</td>
<td>493-5</td>
<td>17-5</td>
<td>-6</td>
<td>510-0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-93</td>
<td>7</td>
<td>516-0</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>453-6</td>
<td>11-9</td>
<td>-6</td>
<td>504-6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-94</td>
<td>4-2</td>
<td>509-4</td>
<td>531-0</td>
</tr>
<tr>
<td>23-2</td>
<td>482-1</td>
<td>10-9</td>
<td>-7</td>
<td>503-1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-95</td>
<td>7</td>
<td>508-1</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>479-2</td>
<td>9-3</td>
<td>-7</td>
<td>500-2</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-95</td>
<td>5-2</td>
<td>506-2</td>
<td>531-0</td>
</tr>
<tr>
<td>24-2</td>
<td>480-3</td>
<td>9-6</td>
<td>-8</td>
<td>501-4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-95</td>
<td>7</td>
<td>506-3</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>484-5</td>
<td>8-9</td>
<td>-8</td>
<td>505-8</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-96</td>
<td>0-2</td>
<td>510-7</td>
<td>531-0</td>
</tr>
<tr>
<td>25-2</td>
<td>487-5</td>
<td>10-3</td>
<td>-9</td>
<td>509-1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>7</td>
<td>514-1</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>491-2</td>
<td>6-7</td>
<td>-9</td>
<td>513-3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>7-2</td>
<td>518-3</td>
<td>531-0</td>
</tr>
<tr>
<td>26-2</td>
<td>492-1</td>
<td>5-9</td>
<td>-9</td>
<td>514-1</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-97</td>
<td>7</td>
<td>519-3</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>494-1</td>
<td>7-3</td>
<td>40-0</td>
<td>516-3</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-98</td>
<td>8-2</td>
<td>521-4</td>
<td>531-0</td>
</tr>
<tr>
<td>27-2</td>
<td>496-2</td>
<td>7-1</td>
<td>0</td>
<td>518-7</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-98</td>
<td>7</td>
<td>523-8</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>498-9</td>
<td>9-0</td>
<td>-1</td>
<td>521-6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-99</td>
<td>9-2</td>
<td>526-7</td>
<td>531-0</td>
</tr>
<tr>
<td>28-2</td>
<td>498-3</td>
<td>9-2</td>
<td>-1</td>
<td>521-0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-10</td>
<td>7</td>
<td>526-2</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>497-8</td>
<td>9-8</td>
<td>-2</td>
<td>520-6</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-10</td>
<td>10-2</td>
<td>525-9</td>
<td>531-0</td>
</tr>
<tr>
<td>29-2</td>
<td>497-1</td>
<td>10-1</td>
<td>-2</td>
<td>520-0</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-11</td>
<td>7</td>
<td>525-3</td>
<td>531-0</td>
</tr>
<tr>
<td>-7</td>
<td>494-6</td>
<td>9-0</td>
<td>-2</td>
<td>517-4</td>
<td>..</td>
<td>..</td>
<td>..</td>
<td>-11</td>
<td>11-2</td>
<td>522-6</td>
<td>531-0</td>
</tr>
<tr>
<td>30-2</td>
<td>490-8</td>
<td>11-0</td>
<td>-3</td>
<td>513-5</td>
<td>9-9986</td>
<td>..</td>
<td>..</td>
<td>-12</td>
<td>7</td>
<td>518-7</td>
<td>531-0</td>
</tr>
</tbody>
</table>

**Remarks:**
<table>
<thead>
<tr>
<th>I.</th>
<th>II.</th>
<th>III.</th>
<th>IV.</th>
<th>V.</th>
<th>VI.</th>
<th>VII.</th>
<th>VIII.</th>
<th>IX.</th>
<th>X.</th>
<th>XI.</th>
<th>XII.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sidereal Time.</td>
<td>$G.$</td>
<td>$P. E.$</td>
<td>$z.$</td>
<td>$G_x.$</td>
<td>$\log \rho^3.$</td>
<td>$\log \rho^2.$</td>
<td>$s.$</td>
<td>$s.$</td>
<td>$G_x^*.$</td>
<td>Curve minus Observ.</td>
<td>Remarks</td>
</tr>
<tr>
<td>$b;m$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 30:7</td>
<td>488:8</td>
<td>± 11:8</td>
<td>40:3</td>
<td>511:4</td>
<td>9:9986</td>
<td>0.0000</td>
<td>2:12</td>
<td>+ 3</td>
<td>12:2</td>
<td>516:0</td>
<td>531:0</td>
</tr>
<tr>
<td>31:2</td>
<td>488:6</td>
<td>12:1</td>
<td>-4</td>
<td>511:3</td>
<td>...</td>
<td>...</td>
<td>-12</td>
<td>-7</td>
<td>516:5</td>
<td>531:0</td>
<td>+ 14:5</td>
</tr>
<tr>
<td>.7</td>
<td>487:3</td>
<td>10:8</td>
<td>-1</td>
<td>510:1</td>
<td>...</td>
<td>...</td>
<td>-13</td>
<td>13:2</td>
<td>516:4</td>
<td>531:0</td>
<td>+ 15:0</td>
</tr>
<tr>
<td>32:2</td>
<td>482:4</td>
<td>9:6</td>
<td>-5</td>
<td>505:1</td>
<td>...</td>
<td>...</td>
<td>-13</td>
<td>7</td>
<td>510:2</td>
<td>531:0</td>
<td>+ 20:8</td>
</tr>
<tr>
<td>.7</td>
<td>480:3</td>
<td>6:8</td>
<td>-5</td>
<td>502:9</td>
<td>...</td>
<td>...</td>
<td>-11</td>
<td>14:2</td>
<td>509:2</td>
<td>531:0</td>
<td>+ 22:8</td>
</tr>
<tr>
<td>33:2</td>
<td>480:2</td>
<td>15:6</td>
<td>-6</td>
<td>509:3</td>
<td>...</td>
<td>...</td>
<td>-15</td>
<td>15:2</td>
<td>525:5</td>
<td>531:0</td>
<td>+ 16:5</td>
</tr>
<tr>
<td>.7</td>
<td>466:4</td>
<td>28:0</td>
<td>-6</td>
<td>520:1</td>
<td>...</td>
<td>...</td>
<td>-15</td>
<td>15:2</td>
<td>525:5</td>
<td>531:0</td>
<td>+ 5:5</td>
</tr>
<tr>
<td>34:2</td>
<td>498:8</td>
<td>22:9</td>
<td>-7</td>
<td>522:6</td>
<td>...</td>
<td>...</td>
<td>-16</td>
<td>7</td>
<td>528:1</td>
<td>531:1</td>
<td>+ 3:0</td>
</tr>
<tr>
<td>.7</td>
<td>494:7</td>
<td>26:2</td>
<td>-7</td>
<td>518:4</td>
<td>...</td>
<td>...</td>
<td>-17</td>
<td>16:2</td>
<td>523:8</td>
<td>531:1</td>
<td>+ 7:3</td>
</tr>
<tr>
<td>35:2</td>
<td>490:7</td>
<td>28:6</td>
<td>-7</td>
<td>514:3</td>
<td>...</td>
<td>...</td>
<td>-17</td>
<td>7</td>
<td>519:6</td>
<td>531:1</td>
<td>+ 11:5</td>
</tr>
<tr>
<td>.7</td>
<td>490:5</td>
<td>28:7</td>
<td>-8</td>
<td>514:1</td>
<td>...</td>
<td>...</td>
<td>-17</td>
<td>17:2</td>
<td>519:0</td>
<td>531:1</td>
<td>+ 11:0</td>
</tr>
<tr>
<td>36:3</td>
<td>488:8</td>
<td>29:2</td>
<td>-8</td>
<td>512:5</td>
<td>...</td>
<td>...</td>
<td>-18</td>
<td>7</td>
<td>518:0</td>
<td>531:1</td>
<td>+ 13:1</td>
</tr>
<tr>
<td>.7</td>
<td>481:8</td>
<td>31:5</td>
<td>-9</td>
<td>505:3</td>
<td>...</td>
<td>...</td>
<td>-18</td>
<td>18:2</td>
<td>510:6</td>
<td>531:1</td>
<td>+ 20:5</td>
</tr>
<tr>
<td>37:2</td>
<td>490:4</td>
<td>31:7</td>
<td>-9</td>
<td>504:0</td>
<td>...</td>
<td>...</td>
<td>-19</td>
<td>7</td>
<td>509:3</td>
<td>531:1</td>
<td>+ 21:8</td>
</tr>
<tr>
<td>.7</td>
<td>476:4</td>
<td>31:8</td>
<td>41:0</td>
<td>499:9</td>
<td>...</td>
<td>...</td>
<td>-20</td>
<td>19:2</td>
<td>505:3</td>
<td>531:1</td>
<td>...</td>
</tr>
<tr>
<td>38:2</td>
<td>465:5</td>
<td>28:7</td>
<td>-9</td>
<td>488:7</td>
<td>...</td>
<td>...</td>
<td>-20</td>
<td>7</td>
<td>468:9</td>
<td>531:1</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>449:7</td>
<td>16:4</td>
<td>-1</td>
<td>472:1</td>
<td>...</td>
<td>...</td>
<td>-21</td>
<td>20:2</td>
<td>477:1</td>
<td>531:1</td>
<td>...</td>
</tr>
<tr>
<td>39:2</td>
<td>439:9</td>
<td>12:4</td>
<td>-1</td>
<td>461:8</td>
<td>...</td>
<td>...</td>
<td>-21</td>
<td>7</td>
<td>466:8</td>
<td>531:1</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>439:4</td>
<td>12:4</td>
<td>-2</td>
<td>461:4</td>
<td>...</td>
<td>...</td>
<td>-22</td>
<td>21:2</td>
<td>466:6</td>
<td>531:1</td>
<td>...</td>
</tr>
<tr>
<td>40:2</td>
<td>435:1</td>
<td>14:8</td>
<td>-2</td>
<td>458:1</td>
<td>...</td>
<td>...</td>
<td>-22</td>
<td>7</td>
<td>462:0</td>
<td>531:2</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>432:7</td>
<td>13:0</td>
<td>-3</td>
<td>454:5</td>
<td>...</td>
<td>...</td>
<td>-22</td>
<td>22:2</td>
<td>450:5</td>
<td>531:2</td>
<td>...</td>
</tr>
<tr>
<td>41:2</td>
<td>433:4</td>
<td>13:9</td>
<td>-3</td>
<td>455:4</td>
<td>...</td>
<td>...</td>
<td>-23</td>
<td>7</td>
<td>460:4</td>
<td>531:2</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>437:2</td>
<td>15:5</td>
<td>-4</td>
<td>459:5</td>
<td>...</td>
<td>...</td>
<td>-23</td>
<td>23:2</td>
<td>464:5</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>42:2</td>
<td>440:4</td>
<td>13:1</td>
<td>-4</td>
<td>462:9</td>
<td>...</td>
<td>...</td>
<td>-24</td>
<td>7</td>
<td>467:9</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>437:8</td>
<td>18:0</td>
<td>-5</td>
<td>460:3</td>
<td>...</td>
<td>...</td>
<td>-25</td>
<td>24:2</td>
<td>465:0</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>43:2</td>
<td>433:5</td>
<td>17:8</td>
<td>-5</td>
<td>461:2</td>
<td>...</td>
<td>...</td>
<td>-25</td>
<td>7</td>
<td>466:3</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>440:2</td>
<td>17:5</td>
<td>-6</td>
<td>463:0</td>
<td>...</td>
<td>...</td>
<td>-26</td>
<td>26:2</td>
<td>468:2</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>44:2</td>
<td>445:3</td>
<td>16:4</td>
<td>-6</td>
<td>468:5</td>
<td>...</td>
<td>...</td>
<td>-26</td>
<td>7</td>
<td>474:0</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>445:6</td>
<td>16:2</td>
<td>-7</td>
<td>468:9</td>
<td>...</td>
<td>...</td>
<td>-27</td>
<td>26:2</td>
<td>471:3</td>
<td>531:3</td>
<td>...</td>
</tr>
<tr>
<td>45:2</td>
<td>447:7</td>
<td>14:0</td>
<td>-7</td>
<td>471:2</td>
<td>9:9995</td>
<td>...</td>
<td>-27</td>
<td>7</td>
<td>470:5</td>
<td>531:4</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>449:9</td>
<td>13:6</td>
<td>-8</td>
<td>473:6</td>
<td>...</td>
<td>...</td>
<td>-27</td>
<td>27:2</td>
<td>478:9</td>
<td>531:4</td>
<td>...</td>
</tr>
<tr>
<td>46:2</td>
<td>448:0</td>
<td>12:7</td>
<td>-8</td>
<td>471:7</td>
<td>...</td>
<td>...</td>
<td>-28</td>
<td>7</td>
<td>476:9</td>
<td>531:4</td>
<td>...</td>
</tr>
<tr>
<td>.7</td>
<td>447:5</td>
<td>12:4</td>
<td>-9</td>
<td>471:2</td>
<td>...</td>
<td>...</td>
<td>-28</td>
<td>28:2</td>
<td>470:6</td>
<td>531:4</td>
<td>...</td>
</tr>
<tr>
<td>47:2</td>
<td>441:9</td>
<td>9:6</td>
<td>-9</td>
<td>465:4</td>
<td>...</td>
<td>...</td>
<td>-28</td>
<td>7</td>
<td>470:7</td>
<td>531:5</td>
<td>...</td>
</tr>
</tbody>
</table>

The observations from 10° 37' to 10° 47', being (through some unrecognized disturbance) much too low, were not utilized for the construction of the final curve.
<table>
<thead>
<tr>
<th>I. Sidereal Time</th>
<th>II. G.</th>
<th>III. P. E.</th>
<th>IV. z.</th>
<th>V. G₂</th>
<th>VI. log ρ₂</th>
<th>VII. log R²</th>
<th>VIII. ε.</th>
<th>IX. Sid. Time from Middle of Eclipse</th>
<th>X. G₉.</th>
<th>XI. G₉ Curve</th>
<th>XII. Curve minus Observ.</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>b m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 22-2</td>
<td>487-0</td>
<td>± 21-3</td>
<td>48-8</td>
<td>523-0</td>
<td>9-9984</td>
<td>0-0000</td>
<td>2-66</td>
<td>+ 4 3-7</td>
<td>530-6</td>
<td>532-3</td>
<td>+ 1-7</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>490-8</td>
<td>20-1</td>
<td>-9</td>
<td>527-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>534-8</td>
<td>532-3</td>
<td>- 2-5</td>
<td></td>
</tr>
<tr>
<td>22-2</td>
<td>491-8</td>
<td>19-9</td>
<td>46-0</td>
<td>528-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>536-2</td>
<td>532-3</td>
<td>- 3-9</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>490-2</td>
<td>20-4</td>
<td>0</td>
<td>527-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>534-6</td>
<td>532-3</td>
<td>- 2-3</td>
<td></td>
</tr>
<tr>
<td>24-2</td>
<td>493-6</td>
<td>17-6</td>
<td>0</td>
<td>530-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>538-4</td>
<td>532-3</td>
<td>- 6-1</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>487-2</td>
<td>13-0</td>
<td>-1</td>
<td>524-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>531-6</td>
<td>532-3</td>
<td>+ 0-7</td>
<td></td>
</tr>
<tr>
<td>25-2</td>
<td>479-6</td>
<td>6-5</td>
<td>-2</td>
<td>516-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>523-6</td>
<td>532-3</td>
<td>+ 8-7</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>479-9</td>
<td>6-1</td>
<td>-4</td>
<td>515-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>525-7</td>
<td>532-3</td>
<td>- 9-8</td>
<td></td>
</tr>
<tr>
<td>27-2</td>
<td>481-7</td>
<td>6-9</td>
<td>-3</td>
<td>519-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>526-7</td>
<td>532-3</td>
<td>+ 5-6</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>482-4</td>
<td>7-6</td>
<td>-5</td>
<td>520-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>522-3</td>
<td>532-3</td>
<td>+ 4-6</td>
<td></td>
</tr>
<tr>
<td>28-2</td>
<td>483-0</td>
<td>7-8</td>
<td>-6</td>
<td>520-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>523-8</td>
<td>532-3</td>
<td>- 3-8</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>488-8</td>
<td>8-1</td>
<td>-6</td>
<td>525-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>538-7</td>
<td>532-3</td>
<td>- 6-4</td>
<td></td>
</tr>
<tr>
<td>29-2</td>
<td>489-8</td>
<td>8-1</td>
<td>-7</td>
<td>528-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>530-3</td>
<td>532-3</td>
<td>- 4-0</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>491-7</td>
<td>8-1</td>
<td>-7</td>
<td>530-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>538-7</td>
<td>532-3</td>
<td>- 6-4</td>
<td></td>
</tr>
<tr>
<td>30-2</td>
<td>490-3</td>
<td>10-3</td>
<td>-8</td>
<td>529-5</td>
<td>9-9583</td>
<td></td>
<td></td>
<td></td>
<td>537-4</td>
<td>532-4</td>
<td>- 5-0</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>492-8</td>
<td>9-8</td>
<td>-8</td>
<td>532-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>540-9</td>
<td>532-4</td>
<td>- 7-9</td>
<td></td>
</tr>
<tr>
<td>31-2</td>
<td>499-1</td>
<td>13-3</td>
<td>-9</td>
<td>539-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>547-4</td>
<td>532-4</td>
<td>- 5-0</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>501-6</td>
<td>12-9</td>
<td>47-0</td>
<td>542-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>550-0</td>
<td>532-4</td>
<td>- 17-6</td>
<td></td>
</tr>
<tr>
<td>32-2</td>
<td>500-7</td>
<td>13-1</td>
<td>-0</td>
<td>541-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>549-5</td>
<td>532-4</td>
<td>- 17-1</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>499-2</td>
<td>14-6</td>
<td>-1</td>
<td>540-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>548-0</td>
<td>532-4</td>
<td>- 15-6</td>
<td></td>
</tr>
<tr>
<td>33-2</td>
<td>503-8</td>
<td>15-7</td>
<td>-2</td>
<td>543-7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>531-8</td>
<td>532-4</td>
<td>- 19-4</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>504-4</td>
<td>15-9</td>
<td>-2</td>
<td>545-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>542-2</td>
<td>532-4</td>
<td>- 21-8</td>
<td></td>
</tr>
<tr>
<td>34-2</td>
<td>503-6</td>
<td>16-2</td>
<td>-3</td>
<td>545-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>538-5</td>
<td>532-4</td>
<td>- 21-1</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>501-4</td>
<td>16-1</td>
<td>-3</td>
<td>543-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>531-2</td>
<td>532-4</td>
<td>- 18-8</td>
<td></td>
</tr>
<tr>
<td>35-2</td>
<td>499-5</td>
<td>19-7</td>
<td>-4</td>
<td>541-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>549-4</td>
<td>532-4</td>
<td>- 17-0</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>499-7</td>
<td>22-8</td>
<td>-5</td>
<td>555-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>542-7</td>
<td>532-4</td>
<td>- 16-3</td>
<td></td>
</tr>
<tr>
<td>36-2</td>
<td>488-9</td>
<td>20-1</td>
<td>-5</td>
<td>530-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>582-7</td>
<td>532-4</td>
<td>- 16-3</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>485-3</td>
<td>19-2</td>
<td>-6</td>
<td>526-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>534-6</td>
<td>532-4</td>
<td>- 2-2</td>
<td></td>
</tr>
<tr>
<td>37-2</td>
<td>483-8</td>
<td>19-3</td>
<td>-7</td>
<td>525-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>538-7</td>
<td>532-4</td>
<td>- 0-7</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>482-6</td>
<td>19-1</td>
<td>-7</td>
<td>523-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>531-9</td>
<td>532-4</td>
<td>+ 0-5</td>
<td></td>
</tr>
<tr>
<td>38-2</td>
<td>479-7</td>
<td>17-4</td>
<td>-8</td>
<td>521-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>528-9</td>
<td>532-5</td>
<td>+ 3-6</td>
<td></td>
</tr>
<tr>
<td>-7</td>
<td>474-0</td>
<td>13-9</td>
<td>-8</td>
<td>515-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>522-9</td>
<td>532-5</td>
<td>+ 9-6</td>
<td></td>
</tr>
<tr>
<td>39-2</td>
<td>471-7</td>
<td>13-0</td>
<td>-9</td>
<td>512-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>520-7</td>
<td>532-5</td>
<td>+ 11-8</td>
<td></td>
</tr>
<tr>
<td>I. Sidereal Time.</td>
<td>II. G.</td>
<td>III. P. E.</td>
<td>IV. z.</td>
<td>V. G.</td>
<td>VI. $\log p^2$</td>
<td>VII. $\log E'^2$</td>
<td>VIII. $\epsilon$.</td>
<td>IX. Sid. Time from Middle of Eclipse.</td>
<td>X. G.*</td>
<td>XI. $G^*$ Curve.</td>
<td>XII. Curve minus Observ.</td>
<td>Remarks</td>
</tr>
<tr>
<td>------------------</td>
<td>--------</td>
<td>-----------</td>
<td>-------</td>
<td>------</td>
<td>-------------</td>
<td>--------------</td>
<td>--------------</td>
<td>----------------------------------</td>
<td>-------</td>
<td>--------------</td>
<td>-------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>h m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 39-7</td>
<td>474-1</td>
<td>± 14-3</td>
<td>47-9</td>
<td>515-4</td>
<td>9:9983</td>
<td>0:0000</td>
<td>2:85</td>
<td>+ 4 21-2</td>
<td>523-8</td>
<td>532-5</td>
<td>+ 8-9</td>
<td></td>
</tr>
<tr>
<td>40-2</td>
<td>478-4</td>
<td>11-1</td>
<td>48-0</td>
<td>520-4</td>
<td>...</td>
<td>...</td>
<td>-86</td>
<td>-7 528-3</td>
<td>532-6</td>
<td>+ 4-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>481-5</td>
<td>7-8</td>
<td>-1</td>
<td>523-8</td>
<td>...</td>
<td>...</td>
<td>-87</td>
<td>22-2 532-2</td>
<td>532-6</td>
<td>+ 0-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>41-2</td>
<td>477-6</td>
<td>7-9</td>
<td>1</td>
<td>519-9</td>
<td>...</td>
<td>...</td>
<td>-87</td>
<td>-7 523-2</td>
<td>532-6</td>
<td>+ 4-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>476-9</td>
<td>8-0</td>
<td>2</td>
<td>518-6</td>
<td>...</td>
<td>...</td>
<td>-87</td>
<td>23-2 526-9</td>
<td>532-6</td>
<td>+ 5-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>42-2</td>
<td>476-4</td>
<td>8-9</td>
<td>3</td>
<td>519-0</td>
<td>...</td>
<td>...</td>
<td>-88</td>
<td>-7 527-3</td>
<td>532-6</td>
<td>+ 5-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>476-1</td>
<td>8-1</td>
<td>3</td>
<td>518-9</td>
<td>...</td>
<td>...</td>
<td>-88</td>
<td>24-2 527-2</td>
<td>532-6</td>
<td>+ 5-4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>43-2</td>
<td>474-2</td>
<td>8-9</td>
<td>4</td>
<td>517-1</td>
<td>...</td>
<td>...</td>
<td>-89</td>
<td>-7 525-4</td>
<td>532-6</td>
<td>+ 7-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>472-2</td>
<td>8-6</td>
<td>4</td>
<td>515-0</td>
<td>...</td>
<td>...</td>
<td>-90</td>
<td>-7 521-6</td>
<td>532-6</td>
<td>+ 11-0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>44-2</td>
<td>470-3</td>
<td>9-3</td>
<td>5</td>
<td>513-3</td>
<td>...</td>
<td>...</td>
<td>-90</td>
<td>-7 512-4</td>
<td>532-6</td>
<td>+ 10-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>465-1</td>
<td>7-2</td>
<td>6</td>
<td>507-7</td>
<td>...</td>
<td>...</td>
<td>-91</td>
<td>-7 515-0</td>
<td>532-6</td>
<td>+ 6-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45-2</td>
<td>461-9</td>
<td>7-7</td>
<td>6</td>
<td>504-3</td>
<td>9:9982</td>
<td>0:0000</td>
<td>-92</td>
<td>-7 512-4</td>
<td>532-6</td>
<td>+ 10-0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>461-0</td>
<td>7-7</td>
<td>7</td>
<td>504-6</td>
<td>...</td>
<td>...</td>
<td>-92</td>
<td>-7 514-6</td>
<td>532-6</td>
<td>+ 17-8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>46-2</td>
<td>463-6</td>
<td>8-2</td>
<td>8</td>
<td>506-7</td>
<td>...</td>
<td>...</td>
<td>-92</td>
<td>-7 514-6</td>
<td>532-6</td>
<td>+ 17-8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>463-2</td>
<td>8-1</td>
<td>8</td>
<td>506-4</td>
<td>...</td>
<td>...</td>
<td>-93</td>
<td>28-2 514-6</td>
<td>532-7</td>
<td>+ 18-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>47-2</td>
<td>465-3</td>
<td>9-3</td>
<td>9</td>
<td>509-9</td>
<td>...</td>
<td>...</td>
<td>-93</td>
<td>-7 517-2</td>
<td>532-7</td>
<td>+ 15-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>465-0</td>
<td>9-7</td>
<td>9</td>
<td>508-8</td>
<td>...</td>
<td>...</td>
<td>-94</td>
<td>29-2 517-0</td>
<td>532-7</td>
<td>+ 15-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>48-2</td>
<td>462-3</td>
<td>10-5</td>
<td>0</td>
<td>505-9</td>
<td>...</td>
<td>...</td>
<td>-95</td>
<td>-7 514-1</td>
<td>532-7</td>
<td>+ 18-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>464-9</td>
<td>10-3</td>
<td>1</td>
<td>500-0</td>
<td>...</td>
<td>...</td>
<td>-95</td>
<td>30-2 517-2</td>
<td>532-7</td>
<td>+ 15-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>49-2</td>
<td>466-2</td>
<td>9-7</td>
<td>1</td>
<td>510-7</td>
<td>...</td>
<td>...</td>
<td>-96</td>
<td>-7 519-9</td>
<td>532-7</td>
<td>+ 13-7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>469-7</td>
<td>9-8</td>
<td>2</td>
<td>514-8</td>
<td>...</td>
<td>...</td>
<td>-96</td>
<td>31-2 523-2</td>
<td>532-7</td>
<td>+ 9-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-2</td>
<td>469-4</td>
<td>10-2</td>
<td>3</td>
<td>514-7</td>
<td>...</td>
<td>...</td>
<td>-97</td>
<td>-7 523-2</td>
<td>532-7</td>
<td>+ 9-5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. Explanation of the preceding Table.—Columns I. and II. After the remarks sect. 4 (page 486), no more need be said in explanation of these columns. Each value $G$ is, unless anything to the contrary is mentioned in the last column, the mean of ten differences of eleven consecutive readings of the galvanometer.

**Column III.**—The probable errors in this column are based on the deviation of the single readings from the mean; they give, therefore, a tolerably clear idea of the steadiness of the apparatus. As was to be expected, the very considerable increase in sensitiveness of the thermocouples since 1884 has also increased the probable error of each heat-value $G$. Besides this, a very great increase is naturally to be perceived during the periods of the most rapid change of the lunar radiation. The mean probable errors, the absolute values as well as when expressed in per cents. of $G$, according to the phases of the eclipse stand as follows:

**Before totality.**

<table>
<thead>
<tr>
<th></th>
<th>Average P.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in Divisions of the Galvanometer Scale</td>
</tr>
<tr>
<td>1. Before the first contact with the penumbra (18 observations)</td>
<td>± 8'11</td>
</tr>
<tr>
<td>2. During the progress of the penumbra (81 obs.)</td>
<td>± 19'11</td>
</tr>
<tr>
<td>3. During the progress of the shadow (52 obs.)</td>
<td>± 12'75</td>
</tr>
</tbody>
</table>

**After totality.**

<table>
<thead>
<tr>
<th></th>
<th>Average P.E.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in Divisions of the Galvanometer Scale</td>
</tr>
<tr>
<td>4. During the progress of the shadow (76 obs.)</td>
<td>± 14'86</td>
</tr>
<tr>
<td>5. During the progress of the penumbra (88 obs.)</td>
<td>± 13'60</td>
</tr>
<tr>
<td>6. After the last contact with the penumbra (132 obs.)</td>
<td>± 14'55</td>
</tr>
</tbody>
</table>

The increase in the last column during the progress of the shadow is here, of course, chiefly due to the smallness of the values of $G$; the atmospheric and other disturbances (as, for instance, the errors of observation) being the same as during the other periods. The mean probable error of the whole series of 447 observations amounts to 14'55 divisions of the galvanometer-scale, or to 8'55 per cent. of the reading $G$. It appears doubtful whether the sensitiveness of the apparatus can be pushed much further if the mode of observing entirely in the open air be adhered to.

**Columns IV. and V.**—$z$ is the Moon’s true zenith-distance, and $G_z$ the lunar radiation reduced to zenith by means of Dr. Copeland’s table for the extinction of the lunar heat in our atmosphere, given in the *Philosophical Transactions* of the Royal Society for 1873, p. 598.
BOEDDICKER—On Lunar Radiant Heat.

Columns VI. and VII.—The factors \( \log \rho^2 \) and \( \log R^2 \) reduce the values \( G \) to the same distance of the Moon from the Earth and Sun, to those, namely, which correspond to \( 7^h\ 18\cdot5^m \) or the middle of the eclipse.

Column VIII.—\( \epsilon \) denotes the Moon's apparent elongation from the point opposite the Sun (− before, + after full Moon) calculated by the formula

\[
\cos (\pi - \epsilon) = \sin D \sin \delta' + \cos D \cos \delta' \cos (A - a'),
\]

where

\( A \) = the Sun's right ascension,

\( D \) = the Sun's declination,

\( a' \) = the Moon's apparent right ascension,

\( \delta' \) = the Moon's apparent declination.

This formula, where \( (\pi - \epsilon) \) represents approximately the Moon's apparent illuminated phase, is given by Dr. Copeland in the Paper referred to above, p. 593.

Column IX.—Gives the sidereal times counted from the middle of the eclipse (− before, + after).

Column X.—The values \( G_* \) were obtained by multiplying those given in Column V. with the factors in Columns VI. and VII., and further with factors obtained from Dr. Copeland's phase-table (l. c. p. 605), by assuming simple proportionality. This correction for phase—the effect of which is but slight—was applied up to the first and after the last contact with the shadow (up to \( 5^h\ 28\cdot6^m \) and after \( 9^h\ 8\cdot4^m \)) as was done in 1884.

Columns XI. and XII.—The \( G_* \) were now plotted down as ordinates with the times as abscissae, and a curve was carefully drawn and read off. These final most probable quantities are given in Column XI., and their differences from the observations in Column XII. As mentioned before (supra, p. 436), the first value (observed at \( 3^h\ 22\cdot7^m \)) and those obtained from \( 6^h\ 48\cdot2^m \) to \( 8^h\ 30\cdot2^m \) were excluded in drawing this final curve.

The two branches of the heat-curve are reproduced on Plates LIII. and LIV.
II.—Construction of a Curve representing approximately the Change of the Moon's Light during the Eclipse.

1. A short discussion of the heat-curve just obtained is more conveniently deferred till after the means have been supplied to compare it with a curve representing the variations of the lunar light during the eclipse. The dates for the computation of this curve were obtained as follows:

The usual formulæ (Appendix to Nautical Almanac for 1836) furnished for the eclipse:

- Semi-diameter of shadow, \(2558\text{.8}''\)
- Semi-diameter of penumbra, \(4511\text{.8}\)
- Depth of penumbra, \(1953\text{.0}\)
- Diameter of Moon, \(1905\text{.8}\)
- Semi-diameter of Earth (as seen from the Moon), \(3490\text{.1}\)
- Semi-diameter of Sun (as seen from the Moon), \(971\text{.7}\)

I now assumed the depth of the penumbra to be equal to \(80 \times 24\text{.4}'' = 1952\), and for the diameter of the Moon

\[78 \times 24\text{.4}'' = 1903\text{.2}'',\]

and divided the penumbra by concentric circles into 80 zones, so that the difference between the semi-diameters of two successive zones was

\[R^m - R^{m+1} = 24\text{.4}, \quad m = 0, 1, 2 \ldots 80\]

\[R^0 = 4511\text{.8} = \text{radius of penumbra},\]

\[R^{80} = 2559\text{.8} = \text{assumed radius of shadow}.\]

The Moon was now supposed to move uniformly along a semi-diameter of the shadow, and the areas successively cut off by the concentric circles computed by the formula

\[A_n = (\phi_n^m - \frac{1}{2} \sin 2\phi_n^m) \rho^2 + (\theta - \frac{1}{2} \sin 2\theta_n^m) R^{m^2}\]

\[n = 0, 1, 2 \ldots 78\]

\[m = 0, 1, 2 \ldots 80\]

where \(\rho = 951\text{.6} = \text{the assumed radius of the Moon, and consequently } \frac{2\rho}{78} = 24\text{.4}.''

The angles \(\phi\) and \(\theta\) were obtained from

\[
\frac{\Delta_{m^2} + \rho^2 - R^{m^2}}{2 \Delta_n^m \rho} = \cos \phi_n^m; \quad \frac{\rho \sin \phi_n^m}{R^m} = \sin \theta_n^m.
\]

Here is

\[\Delta_n^m = R^m + \frac{39 - n}{39} \rho\]

the distance between the centre of the penumbra and the centre of the Moon.
Thus we obviously have \( A_0^0 = 0 \), or external contact, and \( A_75^0 = 951 \cdot 6^2 \cdot \pi \), or internal contact between moon and penumbra. Equally \( R^1, R^2 \ldots R^{59} \) will respectively cut off the areas:

\[
\begin{align*}
A_0^1 (= 0), & A_1^1, A_2^1 \ldots A_{75}^1 (= 951 \cdot 6^2 \cdot \pi). \\
A_0^2 (= 0), & A_1^2, A_2^2 \ldots A_{75}^2 (= 951 \cdot 6^2 \cdot \pi), \text{ etc.} \\
A_0^{59} (= 0), & A_1^{59}, A_2^{59} \ldots A_{75}^{59} (= 951 \cdot 6^2 \cdot \pi).
\end{align*}
\]

These areas were rigorously computed for \( m = 0, 10, 20, \ldots 60, 70, 80 \), and, of course, \( n = 0, 1, 2 \ldots 77, 78 \) for each \( m \), and the intermediate values interpolated. The portions of the Moon, lying successively in one special zone \( m \), enclosed by the two concentric circles described with \( R^{m-1} \) and \( R^m \) will then obviously be

\[
A_1^{m-1}, A_2^{m-1} - A_1^m, A_3^{m-1} - A_2^m, \text{ etc. till } A_{75}^{m-1} - A_7^m
\]

where now \( m = 1, 2, 3 \ldots 80 \).

2. I next computed the uneclipsed areas of the Sun (as seen from the Moon) for 80 points of equal distance, thus obtaining 82 values \( A_0^*, A_1^*, A_2^* \ldots A_{80}^*, A_{81}^* \), of which \( A_0^* = 100 \) denotes the full, and \( A_{81}^* = 0 \) the totally eclipsed Sun as seen from the Moon during the progress of the eclipse. These quantities, which represent approximately the luminosity of the successive penumbral zones—if we neglect the decrease of the Sun’s light towards its limb—were plotted down in a curve, and the numbers corresponding to the middle point of each zone read off. These values

\[
F_o (=100), F_1, F_2, \ldots F_{59}, F_{81} (=0)
\]

are the light-factors, with which the portions of the Moon which lie in the corresponding zones of the penumbra have to be multiplied in order to represent the Moon’s luminosity during the progress of the eclipse. At any particular moment—that, for instance, of internal contact between Moon and penumbra, the Moon’s luminosity will then be expressed by

\[
A_{75}^1 \cdot F_1 + (A_{77}^2 - A_{75}^1) \cdot F_2 + (A_{76}^3 - A_{75}^2) \cdot F_5 + \ldots \\
+ (A_{73}^{m-1} - A_{75}^{m-1}) \cdot F_m + \ldots + (A_2^{77} - A_3^{78}) \cdot F_{77} + A_1^{78} \cdot F_{78}.
\]

Thus 159 quantities were deduced which represent, with considerable approximation, the changes of the Moon’s light during the progress of the eclipse, i.e. during the Moon’s motion through the penumbra into the shadow.
3. It may be worth while once more to recapitulate the assumptions at variance with the facts which I made in order to simplify the computation. It was assumed that

a. the diameter of the Moon was \(1903.2''\), instead of \(1905.8''\);
b. the diameter of the shadow was \(2559.8''\), instead of \(2558.8''\);
c. the Moon moved uniformly along a semi-diameter of the penumbra;
d. the Sun's light was uniform;
e. the Moon's light was uniform.

I do not think that these deviations from reality seriously affect the accuracy of the result as far as our present purpose is concerned.

4. The values of the lunar heat taken from the final curve (Plates LIII. and LIV.) were next expressed in per cents. of the value of \(4^{8}9.2''\), viz. 658-0, and the two curves (light and heat) were drawn on the same piece of paper with the time as abscissae and the light- and heat-values as ordinates. These curves are reproduced on Plate LV., the quantities on which they are based (to tenths of per cents., and from 5 to 5 minutes only) follow below in tabular form. For the sake of comparison I have added on the same plate and in the same Table the observations made and the light-curve computed in 1884. The time is counted from the middle of the eclipse in each case. It will be seen that I have added hypothetical values during totality, which are simply obtained by connecting in the most probable manner the two observed branches of the heat-curves, and which obviously can only give a somewhat vague idea of the course the curves would have taken had observing been possible.

In comparing the curves of 1884 and 1888 the difference of the magnitudes of the two eclipses must be borne in mind. I add, therefore, here the necessary data, from which it will be seen that the more recent eclipse lasted 12 minutes longer than its predecessor.
### Table II.

**Lunar Light and Radiant Heat during the Total Eclipses of October 4, 1884, and January 28, 1888, Expressed in Per Cents. of Full Moon Radiation.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Middle of</td>
<td></td>
<td></td>
<td>Middle of</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eclipse.</td>
<td></td>
<td></td>
<td>Eclipse.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C's light</td>
<td></td>
<td></td>
<td>C's light</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>C's heat</td>
<td></td>
<td></td>
<td>C's heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>- 3h 10m</td>
<td>100.0</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>5</td>
<td>100.0</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>0</td>
<td>100.0</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>2 55</td>
<td>98.8</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>50</td>
<td>97.8</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>45</td>
<td>96.4</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>40</td>
<td>94.6</td>
<td>. .</td>
<td>100.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>35</td>
<td>92.5</td>
<td>. .</td>
<td>98.7</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>20</td>
<td>90.3</td>
<td>. .</td>
<td>97.4</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>15</td>
<td>79.2</td>
<td>. .</td>
<td>88.1</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>10</td>
<td>74.5</td>
<td>. .</td>
<td>83.1</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>5</td>
<td>69.0</td>
<td>. .</td>
<td>77.1</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>0</td>
<td>62.5</td>
<td>. .</td>
<td>70.3</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>1 55</td>
<td>55.1</td>
<td>. .</td>
<td>62.5</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>50</td>
<td>47.7</td>
<td>. .</td>
<td>54.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>45</td>
<td>40.7</td>
<td>. .</td>
<td>45.4</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>20</td>
<td>33.6</td>
<td>. .</td>
<td>37.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>25</td>
<td>23.7</td>
<td>. .</td>
<td>29.4</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>20</td>
<td>14.7</td>
<td>. .</td>
<td>16.0</td>
</tr>
<tr>
<td>. .</td>
<td>. .</td>
<td>20</td>
<td>10.1</td>
<td>. .</td>
<td>10.9</td>
</tr>
<tr>
<td>8-6</td>
<td>10</td>
<td>15</td>
<td>7.0</td>
<td>. .</td>
<td>6.8</td>
</tr>
<tr>
<td>9-3*</td>
<td>9-3*</td>
<td>10</td>
<td>5.4</td>
<td>. .</td>
<td>3.9</td>
</tr>
<tr>
<td>9:4</td>
<td>7-3*</td>
<td>5</td>
<td>4.5</td>
<td>. .</td>
<td>1.8</td>
</tr>
<tr>
<td>2-9</td>
<td>5-8</td>
<td>0</td>
<td>4.0</td>
<td>. .</td>
<td>0.6</td>
</tr>
<tr>
<td>1-2</td>
<td>4-6</td>
<td>0</td>
<td>3.6</td>
<td>. .</td>
<td>0.1</td>
</tr>
<tr>
<td>0-3</td>
<td>3-6</td>
<td>0</td>
<td>3.0</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-1</td>
<td>3-0*</td>
<td>50</td>
<td>2.7</td>
<td>. .</td>
<td>1.0</td>
</tr>
<tr>
<td>0-0</td>
<td>2-7*</td>
<td>45</td>
<td>2.4</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>2-4*</td>
<td>40</td>
<td>1-9</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>2-2*</td>
<td>35</td>
<td>1-7</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>2-1*</td>
<td>30</td>
<td>1-6</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>1-9*</td>
<td>25</td>
<td>1-5</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>1-7*</td>
<td>20</td>
<td>1-4</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>1-6*</td>
<td>15</td>
<td>1-3*</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>1-4*</td>
<td>10</td>
<td>1-2*</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>1-0*</td>
<td>5</td>
<td>1-0*</td>
<td>. .</td>
<td>0.0</td>
</tr>
<tr>
<td>0-0</td>
<td>1-0*</td>
<td>0</td>
<td>1-0*</td>
<td>. .</td>
<td>0.0</td>
</tr>
</tbody>
</table>

**Note.**—The figures marked with an asterisk (*) are hypothetical only.
III.—Discussion of the Observations.

1. Decrease of heat before the first contact with the penumbra.

It might be alleged that this decrease is nothing but a result of the mode in which the final heat-curve has been constructed, and is as such of a purely arbitrary character, and not concordant with actual facts. A glance at Plate LIII. will, however, suffice to show that such can hardly be the case. I also add that I drew the curve as much as possible without any bias, keeping myself all the time carefully in ignorance of the different phases of the eclipse. I think it will have to be admitted that the curve could hardly have been drawn differently. Even the assumption that the decrease of heat did not begin until 4° 20' or 22' would not agree with the observations, and could not be made without necessitating a sudden and inadmissible bend of the curve at about 4° 23'.

And further, if we assign any weight to the first observation of 3° 22·7', even allowing it to be erroneous to a very considerable degree—the lunar heat would be run up, as it were, to over 670 at 4° 20', and to about 700 at 3° 23', or about an hour before the beginning of the eclipse. Thus a still earlier and, I think, altogether incredible decrease of heat would be brought about. Not that I consider the beginning of the decline at 4° 9·2' as indicated by the finally adopted curve on Plate LV. any more probable. For I find that at that epoch the vertical distance of the Earth’s centre from the nearest common tangent of Moon and Sun amounted to round 4685 miles. If we subtract from this the mean semidiameter of the Earth, it would leave 725 miles as the approximate height of the Earth’s atmosphere. This inadmissible amount shows that our observations are too much affected by disturbing influences as to admit of an accurate determination of the height at which the terrestrial atmosphere begins to absorb the solar heat. But they enable us to draw a lower limit for this height. It is evident, namely, that at 4° 24', or about 3 minutes before the first contact with the penumbra, the decrease of heat has definitely set in. And this indicates a height of heat-absorbing atmosphere of our Earth of not less than 190 miles. In any case, however, this result—though of considerable interest—must be received with caution until it has been confirmed by further observations.

2. During the progress of the penumbra the decrease of heat is decidedly more rapid than that of light. This must be chiefly due to the advance of the Earth’s atmosphere, which would absorb a greater proportion of the heat than of the light-rays. At first the heat-curve is not very steep. This was to be expected, as at first only those portions of the lunar surface are cut off which have the Sun near the horizon, and must, therefore, be considerably colder than the central portions. As the shadow advances these central parts of the Moon become rapidly
eclipsed. The heat-curve consequently grows steeper, and becomes more parallel with the light-curve. Finally, the decrease of heat slackens again, and the curve begins to inflect, as now only the colder areas of the lunar surface reflect towards the Earth.

3. At 6° 2'7", or 26° 7". before totality, the heat-curve intersects the light-curve, or, in other words, the emitted heat begins to preponderate over the reflected one. The equilibrium between both kinds of heat, therefore, takes place at 6° 2'7", when the total amount measured is about 7·3° of the Full Moon value. It is of interest to compare these facts with those observed during the former eclipse. Though we can only approximately tell the point of intersection in 1884 (since direct observations were not obtained) there cannot be much doubt that it fell at or near 21° 11·7", or about 28 minutes before totality, when the total amount of heat was 9·2° of Full Moon heat. The difference was to be expected, and is evidently mainly—if not exclusively—due to the greater magnitude of the more recent eclipse. It is, however, to be remarked here, that the heat observed in 1884 before totality is almost certainly too small, as observations were repeatedly interrupted by clouds. Thus it becomes probable, that the intersection between the two curves in 1884 took place somewhat earlier than assumed above, though, of course, an estimate which shall come nearer the truth cannot now be given.

4. In examining the hypothetical heat-curves during totality (see also page 505) the striking point is this, that during both eclipses the last residuum of heat must have been very small. The probable minimum falls in 1888 about two minutes before the end of totality with about 0·4°, and in 1884 about ten minutes before the end of the total phase with about 1°. This small residuum would evidently represent emitted heat only—its amount is so slight that its reality is somewhat doubtful. It also falls to such an extent below the probable error of the observations, that it would certainly not have been perceptible to our apparatus in its present construction had direct observing been practicable. Yet the character of the curves on Plate LV. seems to give sufficient evidence that the lunar heat was at no time actually reduced to zero. Referred to the times counted from the middle of the eclipse, we have in 1884 a lagging of the heat-minimum behind the light-minimum of about 35 minutes, in 1888 of about 45 minutes—a difference again due to the different durations of the two eclipses. From these remarks it would have been expected that the heat-values before the middle of the eclipse in 1884 should have been larger (instead of smaller) than the corresponding quantities of 1888. This anomaly may find its explanation in what has been said in the preceding paragraph about the uncertainty of the observations made in 1884 before the beginning of the total phase.
The point of intersection after totality in 1884 fell at 23h 28·5m (or 62 minutes after the middle of the eclipse) with 1·8 % of heat; in 1888 it fell near 8h 18·5m, with 0·6 %. The data of 1888 are constructed hypothetical ones; those of 1884 were actually observed.

5. After the point of intersection the heat-curve (of 1888) keeps almost parallel to the axis of the abscissae for about six minutes; then it begins to rise again, at first slowly, then with increasing rapidity, keeping all the time at a considerably greater distance from the light-curve than before totality. At the moment of the last contact with the shadow, for instance, this distance amounts to 17½ % against 6½ % at the first contact. The same rapid rise was observed in 1884. But the curve of 1884 continued practically parallel to the light-curve till about 15 minutes after the last contact with the shadow, whereas the curve of 1888 assumes a peculiar S-shaped bend with the greatest elongation from the light-curve shortly after the last contact with the shadow. I am inclined to consider this bend as the result of some (most probably atmospheric) disturbance, and to believe the more parallel course in 1884 the more plausible one. This would mean that the above-mentioned difference between heat and light-curve ought to be reduced from 17½ % to about 15 % against 9½ % at the corresponding moment in 1884.

I need hardly add that such an atmospheric disturbance need not necessarily have occurred at the place of observation, but may have taken place in those regions of our atmosphere which were transversed by the solar rays before they reached the Moon.

6. About 16 minutes after the last contact with the shadow in 1884, and about 17 minutes after the corresponding contact in 1888 the increase of heat begins to become gradually less and less, and in 1888 all but ceases about 7 minutes before the last contact with the penumbra when the total amounts to 80·6 %. Up to 1h 30m after this last contact this quantity increases only to 81 % of Full Moon heat. In 1884 the Moon's heat measured 38m after the last contact with the penumbra was 86·8 % of the Full Moon value, so that, generally speaking, a remarkable agreement between the observations has been established. In detail, however, there exists a considerable difference. For whereas in 1888 the heat-curve—as indicated before—remains practically parallel to the light-curve from 7 minutes before the last contact with the penumbra, it continued to rise slowly but unmistakably in 1884 till about 14 minutes after the end of the eclipse, and only then showed some approach to parallelism to the light-curve. It would be difficult to say which of the two courses is the more probable one. A glance at Plate LIV. leads, however, to the following consideration in favour of the course of 1884. From this plate it is obvious that at about 8h 10m some (probably atmospheric) disturbance set in,
which, gradually increasing, ended (as far as observed) in reducing the lunar heat to 480 divisions of the galvanometer-scale shortly after 8h 30m. Unfortunately I then stopped observing for 30 minutes, so that the recovery of the curve (which certainly must have taken place during this interruption) was not recorded. The character of the curve depends, therefore, essentially on the observations obtained after the interruption, and it is not unlikely that all these last observed quantities are still to some extent affected by the preceding disturbance, and, consequently, somewhat too small.

7. A satisfactory explanation of the deficiency of lunar heat after the end of the eclipse, in spite of the rapid fall to almost zero during the first half of it, I have as yet been unable to find. One fact, however, which may have some bearing on the question I may here mention, viz. that the heat-values of 1884 and 1888 corresponding to the last contact with the shadow and to the last contact with the penumbra seem to be inversely proportional to the times elapsed since the beginning of the two eclipses. We obtain, namely, under the assumption of such a proportionality for the heat at these two epochs in 1884, the figures 38.2°/o and 83.9°/o, while the actually observed quantities were 41.4°/o and 85.2°/o. If this proportionality were actually established—which is at present not the case as far as my observational material goes—it would seem to indicate that the amount of lunar heat transmitted by our atmosphere depends in some way on the amount previously absorbed. The facts would perhaps have to be imagined as follows. The heat immediately reflected by the Moon passes almost undiminished through the atmosphere, and thus causes the rapid rise after totality, while the emitted heat is largely absorbed, so much the more the cooler the atmosphere is. Thus this absorbed quantity of heat increases steadily with the progress of the eclipse; it reaches a maximum towards the end of totality (or, in other words, the total measured becomes a minimum at this epoch) and begins then steadily to decrease again. The heat measured after the end of the eclipse falls thus short of the Full Moon value by the amount of emitted heat which the atmosphere has absorbed, and rises slowly until the atmosphere is, so to speak, saturated, or the maximum of possible absorption has taken place, i.e. until the quantity of heat corresponding to Full Moon has been reached. The total heat measured after an eclipse must thus be inversely proportional to the duration of an eclipse. If the above reasoning holds good, the gradually rising heat-curve of 1884 would be the more probable one. It is well known that the idea of a very considerable absorption of the lunar heat by our atmosphere was familiar to Sir John Herschel, as seen from the following remarks (Outlines of Astronomy, 1873, p. 285):—"Though the surface of the Full Moon exposed to us must necessarily be very much heated, ... yet we feel no heat from it. ... No doubt, therefore, its heat (conformably to what is observed
of that of bodies heated below the point of luminosity) is much more readily absorbed in transversing transparent media than direct solar heat, and is extinguished in the upper regions of our atmosphere, never reaching the surface of the Earth at all. Some probability is given to this by the tendency to disappearance of clouds under the Full Moon, [the italics are Sir John’s] a meteorological fact (for as such we think it fully entitled to rank), for which it is necessary to seek a cause, and for which no other rational explanation seems to offer.”

8. Another explanation of our anomaly might be based on the following paragraph from E. Neison, The Moon (1876), p. 35:

“Hitherto no reference has been made to a question of very considerable influence in the consideration of the questions connected with the lunar surface, and that is with regard to purely local atmospheric conditions; for from a number of different observations it has been considered that from local action some vapours may rise from the surface and play an important part in the questions connected with selenography. Reasoning from the known condition of the material constituting the terrestrial surface, it seems not unlikely that when exposed to the greater temperature to which it has been found that the surface of the Moon is in part exposed, some such local atmospheric conditions may well arise; and that a purely local covering to the surface may well occur in the interior of a deep formation, from the presence of some constituent of the surface, first expelled by the heat and then reabsorbed on cooling. Of the terrestrial surface strata, for example, exposed to the condition under which the Moon exists, few, if any, would be found where this might not be expected to occur in some degree, and such would be most naturally supposed to occur in the interior of the deeper lunar formations where the last influence of any aqueous vapour might be expected to be manifested.”

From this remark we should conclude that during the progress of an eclipse a steady absorption of vapour would take place, by which some heat would be developed. After the eclipse the atmosphere would emanate again, and during this process a certain amount of heat would be conserved or bound until the whole of the atmosphere is set free. By this amount of heat the total measured after the eclipse should fall short of the Full Moon value. Under these circumstances the heat-curve of 1888 after the last contact with the penumbra would be the more probable one. For it should run parallel to the axis of the abscissæ until the lunar vapourous atmosphere is fully developed, and should then rather suddenly rise up to the Full Moon value.

It may, of course, be possible that both the hypotheses discussed hold good and are together adequate in bringing about the observed anomaly.

The above theories I only mention tentatively and with considerable diffidence. Yet any attempt at explaining a so far unexplainable phenomenon may, I think, be of some use for future investigations.
Conclusion.

In conclusion I enumerate a series of observations which the preceding pages have shown to be decidedly desirable and in part possible for the same apparatus—observations which, as far as feasible, I have already begun, and shall lay before the public when tangible results have been obtained.

a. The debatable decrease of heat before the commencement of the eclipse requires confirmation or the reverse as the case may be. The best way to obtain this will consist in observing the near approaches of the Moon to the Earth's shadow—or in observing and discussing the lunar heat at Full Moon on every available occasion.

b. Observations during totality are much needed. I now think that with some precautionary modifications our apparatus may well yield reliable results, and I shall certainly try to obtain them during the next favourable eclipse.

c. The heat after the last contact with the penumbra requires careful measuring during eclipses differing as much as possible in magnitude.

d. It is not unlikely that the behaviour and nature of lunar heat may be recognized if eclipse-observations are carried on through glass. As far as I know, such observations were only made by Professor Langley on one occasion during totality; yet detailed and systematically obtained results appear necessary.

e. Finally, the varying radiation of different parts of the lunar surface—which may have caused many of the irregularities in the results which form the subject of the present paper—requires systematic observing. But this will necessitate either a thorough modification of our apparatus, or perhaps the use of radically different methods of observation.
Lunar Heat,
Total Eclipse 1888 Jan. 28
I. Before Totality.
Lunar Heat,
Total Eclipse 1888 Jan. 28
II After Totality.
Fig. I. Total Lunar Eclipse, 1884 October 4.

Fig. II. Total Lunar Eclipse, 1888, January 28.
TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1-25.—November, 1877, to September, 1883.  (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1-2.—August, 1879, to April, 1882.  (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1-14.—September, 1883, to November, 1887.  (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.


3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicke, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.


5. A Revision of the British Actinia.  Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.


7. Survey of Fishing Grounds, West Coast of Ireland, 1890.  I.—On the Eggs and Larvae of Teleosteans. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.


THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

THE SLUGS OF IRELAND. By R. F. SCHARFF, Ph.D., B.Sc., Keeper of the Natural History Museum, Dublin. Plates LVI., LVII.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORRIGATE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK, PRINTERS TO THE SOCIETY.
1891.

Price Three Shillings.
THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

X.

THE SLUGS OF IRELAND. By R. F. SCHARFF, Ph.D., B.Sc., Keeper of the Natural History Museum, Dublin. Plates LVI., LVII.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORRIDGE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.
1891.
THE SLUGS OF IRELAND. By R. F. SCHARFF, Ph.D., B.Sc., Keeper of the Natural History Museum, Dublin. PLATES LVI. & LVII.

[Read March 9, 1891.]

The term "Slug," used in the ordinary sense, is applied to snails without an external shell. Anatomically, the slugs cannot be grouped into one distinct family apart from the snails. Even of the few genera inhabiting Ireland, Limax, Agriolimax, and Amalia must be placed in one family with the Helices, to which they are much more closely related than they are to Arion and Geomalacus, the two other Irish genera of slugs.

From a systematic point of view a description of these animals, leaving unmentioned the closely-related snails, may seem rather unscientific, but this work has been undertaken chiefly with a view of solving some of the difficulties regarding the distribution of terrestrial animals; and land snails having been known to be transported by sea, as has been shown by Darwin (Origin of Species, 6th ed., p. 353), are of less importance in this respect than slugs. The sea, which is the principal means of communication for other animals and plants between mainland and island, forms an almost impassable barrier for slugs, sea-water being deadly both to their eggs and themselves; therefore, if we find the slugs of mainland and island agreeing in anatomical characters, we may generally conclude that the island must have had a land connexion with the mainland at some time or other, and the more closely related the forms are, the more recent must have been this connexion.

The slugs of Ireland are very closely related, and in most cases are identical with those on the Continent of Europe. It is not my intention, however, to enter in this Paper more fully into the cause of the geographical distribution of slugs, as I propose to deal with the question in a subsequent communication.

Until quite recently, the tongue, or radula, of Mollusca has formed one of the chief characters in the classification, and the separation of one species from another. Specific distinction was based almost entirely on external characters and on
the structure of the radula; and new species have, in consequence, made their appearance in overwhelming numbers. Simroth (38) changed this unfortunate state of things by the production of an elaborate treatise on the German slugs, in which he bases his classification chiefly on the form of the reproductive organs and the intestine. He showed that the radula is subject to much individual variation, and that it is, perhaps, the most unsuitable portion of the slug’s body for the purpose of classification. By his anatomical investigations he was enabled to reduce considerably the number of European species, as given in such a recent work as that of Westerlund (44). Among a number of species of Limax mentioned in the latter work, fifteen supposed genuine species proved, on examination of the internal organs, to be mere varieties of Limax maximus.

Slugs are not alone of importance as regards the geographica! distribution of animals. I hope to be able to show in a separate chapter that their colour has an important bearing on the subject of colouring in animals generally.

Thompson, in his Natural History of Ireland (43), mentions nine species of slugs as occurring in this country. In the most recent list of Irish Mollusca published in 1888, by Taylor and Roebuck (42), this number has been increased to ten, but one of these, as I shall endeavour to show later on, is only a variety. I shall now add four species to the list of Irish slugs, one of which, however, has already been recorded by Roebuck (35), in the Journal of Conchology. All these thirteen species, with the exception of one, are also found in Great Britain. This one species, viz. Geomalacus maculosus, is not only absent from Great Britain, but also from France and Germany. It appears again in Northern Spain, in the province of Asturias. In Ireland it has hitherto only been found in the County Kerry. This part of Ireland has yielded so many peculiar animals and plants that it deserves very much more attention than it has hitherto received. A thorough scientific investigation of that interesting county would, no doubt, reveal a number of forms new to the British fauna and flora.

The thirteen species of Irish slugs belong to five genera, viz. Limax, Agriolimax, Amalia, Arion, and Geomalacus. In most of the British text-books, the three first are united under the genus Limax, but the reasons for separating them will be found under the headings of the respective genera. Lessona and Pollonera (21), and others, have placed the very common Irish slug Limax marginatus (= arborum) in a separate genus, Lehmannia, but I have not thought it advisable to adopt this subdivision of the remaining species of Limax.

The species of the three first genera can be very readily distinguished from those of the genus Arion, by the absence of the candal gland. This gland is present in Geomalacus, but it is not nearly so conspicuous as in Arion, in which its triangular opening at the end of the body is well seen.

The colour of the mucus is not of very great importance, but it is rather
characteristic in *Amaliu carinata* and *Agriolimax agrestis*, being always tough and sticky in the former, and milky in the latter.

The presence of dark lateral bands in most slugs from the very day of their birth, has induced Simroth (38) to regard them as an ancestral character; and, in referring to them, he speaks of the ancestral bands ("Stammbinde"). I merely use the term "lateral bands," although in many cases there appear, besides the original ones, two inner bands, one on each side of the median lighter stripe. These inner bands are separated from the lateral bands by a light stripe, and another similar stripe is on the outer side of the lateral bands. Thus, we distinguish band and stripes—the former dark, the other light in colour.

Simroth, in his monograph (38), has placed much weight in the classification of slugs on the nature of their food. However, my own investigations tend to show that there are fungus-eating species among the Limaces as well as the Arions, whilst most species are not particular as to what sort of food they get. Occasionally they all turn carnivorous, and cannibalism is of frequent occurrence.

The plan adopted in this Paper is to give a general concise synopsis of the various genera and species. Under the heading of each species are paragraphs dealing with: 1. External characters; 2. Anatomy; 3. Reproduction; 4. Habitat; 5. Food; 6. General Distribution. The anatomical part has been curtailed to a considerable extent, and only the general outlines of the reproductive organs have been mentioned, which are sufficient in all cases to distinguish one species from another. More elaborate accounts on the general anatomy will be found in Nunneley's (31) and Simroth's (38) works. Neither the shell nor the radula are mentioned, as they do not afford such easy and reliable evidence in the identification of the species as the reproductive organs.

The only papers ever published on Irish slugs are those of the Rev. B. J. Clarke (3), and Professor Allman (1). Although the former is exhaustive as far as it goes, it deals only with what was then believed to come under the head of the genus *Limax*. Professor Allman was the first to describe *Geomalacus maculosus*. The subsequent publications containing reference to Irish slugs are more of the nature of lists.

In Forbes and Hanley's *History of British Mollusca* (9), a few references are made to Irish slugs; and Thompson, in his *Natural History of Ireland* (43), gives a complete list of the species with which he was acquainted. A Paper by Taylor and Roebuck, entitled "Authenticated materials towards a Land and Freshwater Molluscan Fauna of Ireland" (42), contains the most recent list of slugs, with a good many records of localities from all parts of the country. For the past few years Messrs. Taylor and Roebuck have had in preparation a *Monograph of the Land and Freshwater Mollusca of the British Fauna*, which no doubt, will contain a good deal of useful information on the distribution and
variation of slugs. Mr. Roebuck, especially, has for several years made slugs his principal study, and has worked with great energy in extending our information as regards their distribution in all parts of Great Britain and Ireland. Before writing this Paper I consulted Messrs. Taylor and Roebuck, who in consideration of my only dealing with the most neglected portion of the British Islands, kindly promised their support and assistance in my work. The six volumes of the Journal of Conchology originated by J. W. Taylor contain a large number of references and records of Irish slugs.

The most important Memoirs on European continental slugs are those of Simroth (38) and Lessona and Pollonera (21). The former chiefly deals with the German forms, and the latter with the Italian. As regards the French slugs, Moquin-Tandon's (26) work is still the most reliable. Although more recent observers have added a good many new species, and even genera to the French Fauna, most of them have to be accepted with great caution.

In concluding these preliminary remarks, I must express my sincerest thanks to Messrs. A. G. More, F. W. Moore, J. R. Redding, G. Barrett-Hamilton, H. B. Rathborne, G. H. Carpenter, Rev. A. H. Delap, and Miss Warren, for specimens, and Messrs. Taylor, Hanitsch, Pollonera, and Simroth, for kind advice, or literary help. The latter was good enough to submit to me part of the proof of his forthcoming memoir on the slugs of Portugal and the Azores, which will appear during the course of the present year.

**Synopsis of the Irish Genera.**

A.—Slugs without caudal gland. Pulmonary opening behind the middle of the mantle = Limax, Agriolimax, Amalia.

I.—Mantle with concentric wrinkles = Limax, Agriolimax.
   a. Lateral bands, or a band of spots present, = Limax.
   b. Lateral bands absent = Agriolimax.

II.—Mantle granulated, and with deep horse-shoe shaped groove, = Amalia.

B.—Slugs with caudal gland. Pulmonary opening in front of the middle of the mantle = Arion, Geomalacus.

I.—Caudal gland placed longitudinally = Arion.

II.—Caudal gland placed transversely = Geomalacus.

**Genus I.—**Limax. (Linné, 1758).

Body elongated, keeled towards the tail; wrinkles longitudinal on body, concentric on mantle. Longitudinal bands or bands of spots on body and mantle always present in adult; no caudal gland. Pulmonary opening behind middle
of mantle. Reproductive pore near base of upper tentacles. There is a solid internal shell, and the intestine has six convolutions.

In this genus the body is elongated and often strongly keeled posteriorly. The lateral bands are always present in the Irish species, both on the mantle and body; but they may become obscured by being broken up into spots (L. flavus), or by the general body colour in the adult becoming black throughout. There is no caudal gland. The pulmonary opening is always situated behind a line drawn across the middle of the mantle. The skin externally is wrinkled, but the wrinkles never are so prominent as they are in the genus Arion; they are more pronounced, however, than in Agriolimax and Amalia, where the skin is almost smooth, especially in the latter.

There are invariably six convolutions of the intestine, sometimes with an additional cœcum. The genital opening is just behind the tentacles, and there is a solid internal shell.

There are three anatomically well-defined species of Limax in Ireland: one of them, viz. Limax marginatus (= arborum, Bouch), differs so much in the structure, of the reproductive organs, as well as in that of the radula, that a separate genus was proposed for it by Heynemann. Simroth (38) was the first to suggest that Limax variegatus (= flavus) should be united to this new genus Lehmannia, as both possess a cœcum to the intestine. But although they have this much in common, the reproductive organs in the two species are not so very similar as to make it desirable to unite them. I think that if any division of the genus Limax is made, Limax marginatus (= arborum) and L. variegatus (= flavus) should be placed in separate genera. The presence of a flagellum in the reproductive organs of Limax marginatus (= arborum) also shows some affinity to the genus Agriolimax.

Synopsis of the Irish Species of Limax.

I.—Mantle with dark spots on light ground, or uniformly dark = L. maximus.
II.—Mantle with light spots on darker ground = L. flavus.
III.—Mantle with two lateral dark bands = L. marginatus.

Limax maximus, L.


(Plate LVI., figs. 1 and 2.)

Colour of body generally a reddish-gray, with dark lateral bands on body, continued to the posterior third of mantle, the remainder of which is spotted. Tentacles long; a faint black line runs along outer margin of foot. Intestine without a cœcum.
External characters.—I have attempted to use the markings of the mantle as a method of readily distinguishing the species of *Limax*, but there is another way, though perhaps not altogether scientific, by which *L. maximus* can easily be identified. If the mantle be touched with a pencil or other sharp instrument, the front portion curls round completely towards the source of irritation, whilst in the two other species the same portion of the mantle will be only slightly lifted. Another character by which *L. maximus* (except in very dark specimens) can be distinguished, is a faint black line, running along the external margin of the foot, which is quite absent in *L. flavus* and *L. marginatus*. Moreover, *L. maximus* is always more slender, and its tentacles are almost double the length of those of *L. marginatus*, in specimens of the same size. The largest specimen I have met with about Dublin, measured 110 mm. long, and 9 mm. broad; but I took one in May, near Lough Caragh, Co. Kerry, which in spirit still measures 85 mm. by 14 mm. As a rule, slugs shrink in alcohol to about one-half their length when alive and fully stretched out; but in this case I think the specimen can hardly have been more than 150 mm. long, which is exactly 6 inches. According to Moquin-Tandon (26), they sometimes grow to the length of 170 mm. in France.

We must not draw too rigid rules as to the limits of the specific characters of this species, for it is subject to much variation in colour, though in Ireland it is by no means the most variable of slugs, as it seems to be in Germany, according to Simroth (38).

All the specimens I have examined, whether they were of various shades of gray, or of a dark brownish colour, were anatomically identical. Roebuck, in his British Slug List (35), refers to *Limax cinereo-niger* (Wolff) as a form which is found in Ireland, and which is now separated by the best Continental authorities from *L. maximus*. He does not mention them, but Simroth (38), one of the best authorities, certainly examined the form, and found it to agree with *L. maximus*. Roebuck states, in the same Paper, that there are important differences between the species in the genital apparatus, but he does not say what they consist in. I, myself, have not had an opportunity of examining a specimen which could be referred to this species, although I have had one or two, which were quite dark above, but leaving the foot white.*

The original lateral bands are always present in quite young specimens. On the posterior third of the mantle they assume a horse-shoe shape without being continued anteriorly. Curiously enough, in the adult, the left part of this horse-shoe becomes almost always broken up into spots, whilst at the right side it generally

* I have quite recently obtained a specimen at Glengariff agreeing in every respect with the description given of *cinereo-niger*. On examination I found no difference anatomically between it and a typical *L. maximus*, except in the origin of the retractor muscle of the penis. This confirms the opinion held above that *cinereo-niger* can only be regarded as a variety of *maximus*. 
persists. Thus we usually find that the mantle is uniformly spotted in the adult, except the part between the respiratory orifice and the posterior margin, where we meet with an elongated black mark, the remnant of the lateral band of the mantle. (This is well shown in Reeves' (34) figure of L. maximus.) The general body-colour is usually of a faint reddish-gray, turning into pure gray in spirit, whilst the dark spots and bands often become blue. The tentacles are of a light reddish-violet tint. The mucus, on the nature and colour of which rather too much importance has been placed by previous observers, is whitish, and not nearly so abundant as in L. flavus, and L. marginatus.

Anatomy (Plate LVII., fig. 25).—Both Nunneley (31) and Simroth (38) have given such detailed descriptions of the anatomy, that I need only refer again to the most salient features.

Of the six convolutions of the intestine, four are imbedded in the liver, and two hang freely in the body cavity. The hermaphrodite gland (hg.) is elongated and large, and is connected with the ovisperm-duct (os.) by means of the hermaphrodite duct (hd.) which takes its course through a portion of the albuminiparous gland (ag.). The ovisperm-duct is thick and well convoluted, and separates further down into a vas-deferens or sperm-duct (sp.) and an oviduct (ov.). The former opens into the upper end of a very long penis (p.), to which a strong retractor muscle (rm.) is attached. The lower portion of the penis unites with that of the oviduct at the genital orifice, so that there is no vestibule. The receptaculum seminis (rec.) opens into the lower end of the penis near the junction of the two ducts. Nunneley (31) gives a good figure and description of the reproductive organs, and although he mistook the albuminiparous gland for the testis, this is a comparatively unimportant matter.

Of course, as in all parts of the body, there are variations in the reproductive organs, and it is a matter of opinion whether, in conjunction with external differences in colour, these should be regarded as sufficient to sub-divide the species. Lessona and Pollonera (28), who have published an elaborate monograph on the Italian slugs, are evidently of that opinion, and a good deal may be said in favour of it.

I consider the shell of so little importance as a distinguishing feature that it will be enough to say that it is much larger than in any of the other species.

Reproduction.—The eggs, as far as my observation goes, are deposited in August and September, but I think another deposition takes place earlier in the year. They are very transparent, elastic and slightly yellowish in colour. Their length is 6 mm., and width 4 mm. About a month after their deposition the young appear, and from the first show two distinct lateral bands on the body, reaching to the posterior third of the mantle. The body-colour at this stage is of
a delicate reddish-yellow, the portion of the mantle above the shell being paler, owing to the transparency of the skin.

Its duration of life has generally been fixed at one year. [See Moquin-Tandon (26) and Simroth (38).] I took large specimens on the west coast in May, with reproductive organs almost fully developed, and have everywhere taken numerous half-grown ones in September; therefore I conclude that eggs are laid twice in the year. Lehmann (20) seems to be of the same opinion. It is probable that large specimens owing to the scarcity of food have less chance of surviving winter than small ones, so that comparatively few will be fully developed in the following June. In the West, where the climate is milder, large ones find food more plentifully throughout the winter, and we thus meet with many full-grown specimens by May.

Habitat.—"L. maximus," Miss Warren wrote to me some time ago from Co. Mayo, "is a solitary species, which may be explained by the fact that it is a great traveller." This agrees exactly with my own observation. One finds either a solitary specimen or two not far from one another, but rarely more.

There are frequent references [see Leach (19), Reeve (34), and Simroth (38)] to this slug having been found in cellars in other countries, but neither my predecessors Clarke (3) or Thompson (43), nor myself, have ever met with it in the house. I have found L. maximus in my own garden in Dublin, and in the country everywhere, chiefly in woods, under stones and tree trunks, and near the seashore, almost within high-water mark, but always locally.

Food.—Simroth (38) observes that the spirit in which specimens of L. maximus have been killed is never coloured green. He found that plants containing chlorophyll were always refused, whilst fungi were greedily devoured, and form the staple food of these slugs. When found in the cellar they may also live on meat or the juicy stalks of vegetables.

My experience almost agrees with that of Simroth in the above. The specimens which I kept in captivity only once gnawed at the green leaf of a Campanula after having received no other food for a week.

This species, like many others, occasionally exhibits a strong tendency towards cannibalism. It appeared to me that, especially where one specimen became rather sickly, the others would seize upon it and devour it.

Quite recently Gain (10) published some very interesting observations on the food of slugs. He says—"L. maximus is a very dainty feeder, preferring fungi to all other foods, and it seems to be harmless in the garden." Kew (17) writes on the same subject, "This species feeds freely on bread, and it also ate Russula emetica, but ripe berries of Solanum dulcamara were refused."

General Distribution.—Great Britain, throughout Continental Europe and
Asia Minor; also the islands of Sicily, Corsica, Sardinia, Azores, Madeira, and New Zealand (introduced), and East Coast of North America (introduced).

**Limax flavus, L.**


(Plate LVI., fig. 3.)

Colour of body, lemon or orange-yellow spotted with gray, the spots being arranged in bands. Tentacles bluish. The intestine has a cœcum, but there is no flagellum.

*Synonymy.*—The name “variegatus” of Draparnaud (5), adopted by Moquin-Tandon (26), Simroth (32), and others, is not correct by the law of priority. Lessona and Pollonera (21) have pointed out that we cannot remain in doubt about the identity of Linné’s species with that of Draparnaud, as the former refers to Lister’s (22) figure, which is unmistakable.

*External Characters.*—The species is very constant in its external characters. This slug appears to be of a uniformly lemon-yellow colour; on closer inspection, however, we find that the yellow is obscured to such an extent by a delicate gray, especially on the mantle, that it seems as if there were yellow spots on a gray ground. Towards the sides of the body and mantle the colour becomes more of an orange. Specimens taken in my own cellars were more vividly coloured; they were always of a deep orange-yellow. But the yellow colour in this slug is entirely due to an abundant mucus, covering the body at all times. When it is wiped off, the true body-colour is revealed, which is a dull flesh-tint. Although the secretion from the dermal glands of the back is so intensely yellow, the ordinary mucus of the foot is colourless and very abundant.

The tentacles present a very striking character, being of a delicate blue colour. They are shorter and thicker than in either of the two other species of *Limax*. But the wrinkles are, perhaps, the most characteristic feature in this slug. They are closely set, and have been likened by Simroth (38) to strings of pearls (perlschnurartig).

The largest specimen I have seen was 80 mm. long, by 10 mm. broad; so that it is considerably smaller than the preceding species, but rather broader for its size. Altogether, it is more rounded than *L. maximus*, and there is only a faint indication of a keel at the tail end of the body.

Only once have I seen a specimen which exhibited a trace of a band on one side of the mantle, but never on the body.
Anatomy (Plate LVII., fig. 26).—There are the same six convolutions of the intestine as in the preceding species, but _L. flavus_ is distinguished from it, and resembles the next species, in having a blind process or cæcum attached to the end portion of the intestine. This remarkable feature induced Simroth (38) to unite _L. variegatus_ (= _flavus_) and _L. arborum_ (= _marginatus_) into one sub-genus. This author informs us that Selenka had discovered the presence of the cæcum; however, Nunneley (31) described it thirty years before him. The latter mentions that this cæcum consists of but little more than delicate cellular tissue, that it is always collapsed, and that the contents of the intestine do not pass down it.

The hermaphrodite gland (_hg._) is not so elongated as in _L. maximus_, and is of a light yellow colour, but the shape of the gland naturally varies very much, and is therefore not of importance in the diagnosis of the species. The ovisperm-duct (_os._) seems rather shorter than in _L. maximus_; and the receptaculum seminis (_rec._) is larger, and opens into the lower portion of the oviduct (_ov._).

Reproduction.—The eggs of this species are at once recognized as distinct from those of _L. maximus_. They are provided with a minute sharp point at each end of the longer diameter. Those I examined were 7 mm. long, and 5 mm. broad; but, according to Simroth (38), they vary considerably in size, he having found some measuring 11 mm. long. They are somewhat yellowish in tint, and rather firmer in consistency than those of _L. maximus_. I found them at the end of November in an old tree trunk near Dublin, and the young slugs emerged a few days later. These young ones are much darker than the adults. They are of a somewhat greenish colour, and many of them had a very distinct light stripe running down the back, the sides being darker; otherwise they resemble the adults so much that there is no difficulty in recognizing the species at once.

In the cellars, where this species is common, I have obtained adults up to November, but in December not a single adult was seen. They must have died off, young and half-grown specimens being numerous. The fact of there being half-grown ones in December also proves that a deposition of ova takes place in the early months of summer.

_Habitat._—_L. flavus_ lives chiefly in cellars and kitchens, but it is by no means scarce in the country. I have often taken it in woods under the bark of old trees, along with _L. maximus_—always a number of them together. In Germany it seems to be almost exclusively confined to cellars.

Taylor and Roebuck (42) report its occurrence at Waterford, whilst I have taken it everywhere in the county Dublin; and Thompson (43) records its presence in the North. I have also received specimens from Mr. Barrett-Hamilton from Wexford.
Food.—Clarke (3) states that he kept specimens in confinement on bread, which they eat voraciously. I tried them with campanula leaves, but they would not touch them. Gain (10) found that they eat the stalks of cabbage and lettuce, raw and cooked potatoes, turnips and fruits, but that their favourite food is cream. Of foliage they took only the holly (*Ilex aquifolium*) at first, but he induced them later on to take leaves of the bean plant, bryony (*Bryonia divisa*), *Campanula latifolia*, and others. I have once found them feeding on a large fungus, and as they never colour spirit green, I have no doubt that Simroth (38) is right in concluding that their natural food consists in non-chlorophyllaceous substances.

General Distribution.—Great Britain; throughout continental Europe and Asia Minor; also the islands of Sicily, Sardinia, Madeira, the Azores, and Balearic Isles. It occurs also, but has probably been introduced, on the east coast of North America and Brazil, as well as in Australia and New Zealand.

**Limax marginatus**, Müller.


(Plate LVI., fig. 4.)

Body gelatinous, only slightly keeled towards tail. Colour, generally a reddish gray; dark lateral bands on body, continued to the front of mantle. Tentacles short. A coecum in intestine, and a flagellum attached to penis.

**Synonymy.**—Jeffreys (16), in his text-book, seems to take it for granted that the species described under the above name by Müller (28) is identical with Draparnaud's (5) *marginatus*, although Draparnaud himself did not feel certain, on account of its different habits. What Draparnaud described was either the *Amalia carinata* (Leach) or a closely allied species; for, whilst Müller distinctly mentioned that his species inhabits the beech, Draparnaud’s is a ground slug, and never ascends trees.

**External Characters.**—I have already mentioned that the lateral lyre-shaped bands on the mantle are a most typical character. In very dark specimens these bands may almost disappear; but I have never seen one in which they could not be recognized. The bands alone are sufficient to distinguish this slug from *L. maximus* and *L. flavus*. Moreover, it is distinguished from all other slugs by its gelatinous appearance, and the slightest touch will cause it to give off a most abundant wafery mucus. It never grows to the size of *L. maximus*, with which, by the uninitiated, it might be confounded. The largest specimen I have seen measured 80 mm.
The general body-colour is a reddish or sometimes a bluish gray, which may be more or less obscured by darker bands or spots. In almost all cases a lighter stripe is left, which runs along the middle of the back. The posterior third of the body is carinated, but the keel is not nearly so marked as in *L. maximus*. The ground-colour of the mantle is as a rule lighter than that of the body. The middle portion is gray, and bordered on each side by a strip of light ground colour. The dark lateral bands almost surround the whole, although they do not quite meet in front or behind. The head is reddish gray, but it is also subject to slight variation in colour. The tentacles, as has been remarked before, are about half as long as those of an equal-sized specimen of *L. maximus* (fig. 2), and are somewhat similar in tint.

*Anatomy* (Plate LVII., fig. 27).—The interior of the body-cavity, especially posteriorly, is darkly pigmented. The intestinal convolutions are similar in number and shape to those of the preceding species, and there is also a cecum. The hermaphrodite gland (*hg.*) is smaller than in the two other species of *Limax*, generally dark in colour, and often divided into two portions. The ovisperm-duct (*os.*) is thick and short. The sperm-duct (*sp.*) and penis (*p.*) very short, the latter being distinguished by the presence of a flagellum (*fil.*) which may be looked upon as an accessory gland. The receptaculum seminis (*rec.*) opens, as in *L. maximus*, into the lower portion of the penis.

*Reproduction.*—I kept a number of specimens of this species in captivity from September until December. Eggs were deposited from the end of September till the middle of October, on an average about twenty in a cluster. The sizes varied somewhat, but they were mostly 5½ mm. long by 4 mm. broad, and were extremely like those of *L. maximus*—very transparent and elastic. The young made their appearance exactly four weeks after the deposition of the eggs, and were of a reddish-violet colour throughout. Even at this stage, from the very first day of their birth, they are easily distinguished from *L. maximus*. The tentacles are about 2 mm. long in the latter, while in *L. marginatus* they are only 1 mm. in length. The young *L. marginatus* is born with the lateral bands fully developed, reaching right to the front, whilst in *L. maximus*, as we have seen, they stop short at the posterior third of the mantle. The bands on the body of the young, as Simroth (38) has pointed out, are not equivalent to those in *L. maximus*. In fact, they are not the real lateral bands (Stammbinde), but the inner bands, which appear much later in *L. maximus*. As I found a large number of specimens in September, measuring from 30 to 40 mm., we may conclude that in this species also there must be a deposition of ova at least twice in the year. Simroth (32) believes that this species lives through several years, but I venture to think that more evidence is needed to support this opinion.

*Habitat.*—*Limax marginatus* has a wide range in this country. Both
Thompson (43) and Clarke (3) found it common in the North, on the stems of trees after rain. Taylor and Roebuck (42) report its occurrence from Kerry, Waterford, and other counties. Forbes and Hanley (9) state that they found it plentifully on bare rocks at an elevation of above 1500 feet near Connor Cliffs, above Dingle, in Kerry. It is a very common form around Dublin, but it is peculiar to the open country, and not found in gardens. It is seen both on the trunks of trees and among rocks, and under stones. The Rev. A. H. Delap sent me specimens from the Skelligs Rock agreeing in every respect with the mainland forms. This is a large bare rock, about ten miles from the coast of Kerry. Neither bush nor tree grows on it, and in westerly winds it is enveloped in a mist of spray, the waves beating over the greater part of it. From the Aran Islands in Galway Bay, which are quite bare and rocky, I have also received specimens, and, no doubt, this species occurs on all the islands along the west coast.

Food.—According to Lehmann (20) this slug is both carnivorous and herbivorous, but Simroth's (38) experience goes to show that it only touches animal food when driven by stress of hunger. He also states that the spirit is coloured green, not by the chlorophyll of leaves, but by that contained in lichens, and that the latter constitute the real food of \textit{L. marginatus}.

This is very much my own experience. My captive specimens refused to touch green leaves or fish, and after four weeks they died from starvation. Although these observations are of some importance in establishing the nature of food which slugs live on, further experiments are needed to decide beyond doubt what the natural food of \textit{L. marginatus} consists in. Gain (10) states that the specimens which he kept in captivity would not touch mosses, lichens, or fungi. This may be due to an unsuitable kind of lichen having been chosen, or else that the slugs were, for some reason or other, unwilling to feed at all.

General Distribution.—Great Britain, and the greater part of continental Europe; also the islands of Iceland and Sicily.

\textbf{Genus II. — Agriolimax.} (Malm, 1868.)

Animal keeled only posteriorly. Mantle concentrically striated, the centre of striae being somewhat to the right of median line. There are no bands, and if spots are present they are irregularly scattered over the body. Pulmonary opening behind middle of mantle, and genital pore near tentacles. The intestine has four convolutions, and there is a solid internal shell; no caudal gland.

This genus includes some species which used to form part of the genus \textit{Limax}, and in most modern text-books they are still retained under that denomination. Of course it is much better not to give up an old well-known name too readily; but a large number of species have been found in recent years in various parts of
Europe which may, with our two species, *A. agrestis* and *A. laevis*, be united into one group, differing in many important features from the genus *Limax*. The name *Agriolimax* has been adopted by such authorities as Simroth (38), Lessona and Pollonera (21), and Malm (25), although it is not by all of them used in the same sense. I have adopted Simroth's definition of the genus. The differences in the intestine alone are sufficient to separate the two forms *A. agrestis* and *A. laevis* from the Limaces, but there are additional and not less important differences. *Agriolimax* has only four convolutions of the intestine instead of six, and these four are altogether different in position from those in *Limax*. In the last genus the left lobe of the liver formed the apex of the intestinal sack; in *Agriolimax* it is the right. The reproductive organs do not show any very important difference in the two genera, with the exception, perhaps, of the retractor muscle of the penis. The chief objection to the more general recognition of this genus among Malacologists seems to be in the difficulty of fixing a constant character by which *Agriolimax* may be distinguished from *Limax* externally. Simroth (38), however, has shown, in his excellent monograph, that the species of *Agriolimax* never at any period of their lives possess bands. If in some varieties the irregular concentrations of dark pigment here and there appear to produce a kind of lateral band, we must not be led astray by appearances. In the genus *Limax*, on the other hand, lateral bands are always present, at any rate during youth. They may in later stages unite or break up into irregular spots, but in almost all cases their presence can be easily demonstrated.

The food in *Agriolimax* is different from that of the Limaces. As we have seen the natural diet of the latter is probably fungi and lichens, but *Agriolimax* lives on the higher phanerogamic plants. It is a most destructive pest in the field and garden, whilst the Limaces are comparatively harmless; indeed, they might even be called useful slugs.

**Synopsis of the Irish Species of Agriolimax.**

I.—Mantle about one-third the length of body. Mucus milky = *A. agrestis*.  
II.—Mantle about one-half the length of body. Mucus colourless = *A. laevis*.

*Agriolimax agrestis*, L.


(Plate LVI., figs. 5 and 6).

Body-colour generally of a yellowish-white, irregularly spotted with gray, sometimes of a uniform gray or brown; mantle about one-third the length of body. Slime milky. A cæcum in intestine.
External Characters.—As a rule Agriolimax agrestis may be distinguished from A. laevis by the colour alone. The former is almost always of a dirty yellowish-white colour (fig. 5), either with or without diffuse patches of a darker pigment. The latter may altogether obscure the original body-colour, and produce a bluish slate-coloured slug (fig. 6). I have had two specimens from the Aran Islands, county Galway, which resembled A. laevis in so far as they were of a dark chocolate colour, but the milky slime, the short mantle, and the more pronounced keel were sufficient to pronounce them as mere varieties of A. agrestis. Anatomically they differed in no way from the usual form.

A. agrestis grows to a much greater size than A. laevis, the largest specimen measuring 40 mm. by 5 mm. According to Moquin-Tandon (26) it reaches the length of 60 mm. in France.

In a fully extended specimen the mantle occupies exactly a third of the total length of the body, which is somewhat compressed posteriorly, and there is a well-marked keel reaching from the posterior third to the end of the body. The head and tentacles are faintly violet-coloured, but vary according to the general body tint.

Quite fifty per cent. of the varieties I picked up during the summer in the country near Dublin were of a uniform yellowish-white, the space between the wrinkles being marked by a very light gray, so that the shape of each body-wrinkle was well seen. Once I obtained a perfectly white albino specimen under a heap of hay at Raheny. In November 60 per cent. of the A. agrestis in my garden were of a yellowish-white colour, faintly speckled with gray. On the other hand, of those obtained at the same time from the Aran Islands, 80 per cent. had the ground colour reddish-yellow, but they were uniformly mottled with dark gray, two specimens being almost black. The mucus in this slug is very abundant, and of a milky colour.

Anatomy. (Plate LVII., fig. 28).—There are only four convolutions in the intestine of this species and the next, as has been shown by Nunneley (31), and more recently by Simroth (38). But Nunneley did not notice the small oesum near the terminal convolution of the intestine. Simroth pointed out that it is not homologous with that in Limax, being differently situated. The hermaphroditic gland (hg.) is elongated, and generally the acini composing it are split up like a bunch of grapes. The hermaphroditic duct (hd.) is almost always straight, i.e. not convoluted like that in Limax. Close to the genital pore, the ovisperm-duct (os.) divides into oviduct (ov.) and sperm-duct (sp.). The latter is short and opens into the very large penis (p.). The receptaculum seminis (rec.) is placed at the junction of the penis and oviduct. Near the opening of the sperm-duct into the penis, an accessory gland, the flagellum (fl.), opens into it also, and I found this to vary somewhat in the different specimens I examined.
A Paper dealing with the anatomy and histology of the alimentary canal and the nervous system has recently been published by Dr. Hanitsch (12).

Reproduction.—The eggs are globular and perfectly transparent, measuring 2 mm. in diameter. The specimens I kept in captivity produced only about 30 eggs each, but according to some authorities the same slug may deposit a large number during a short period. Thus, Moquin-Tandon (20) mentions that one specimen has, at different times, produced as many as 300 or even 350 eggs; and, according to the same authority, Leach is stated to have observed two slugs deposit 776 eggs. Although, no doubt, this slug is extremely prolific, I venture to think that further experiments are needed to confirm these observations. The young do not seem to me to present any appreciable differences from the adults.

I have taken specimens with fully developed reproductive organs from March to December. In the latter month and January the large specimens seem to die off, but it is difficult to determine their length of life. Simroth (38) believes that they live only one year.

Habitat.—*Agriolimax agrestis* is to be met with everywhere. It is the commonest, and probably the most destructive of all slugs. The damage done by it in the garden as well as in the field is enormous. It begins its ravages in the evening soon after sunset, and feeds the whole night through until the morning, when it retires for the day into worm-burrows or underneath stones and clods of earth. It seems to be little affected by weather or climate, being equally common on the islands of the west coast, on the mainland, and on the continent of Europe.

This slug is very active, and when touched, it glides through the fingers, leaving a mass of milky slime behind, and rapidly crawls away. As I have mentioned, I have seen the very dark variety only from the Aran Islands. The dark slate-coloured variety, described by Clarke (3), only once occurred to me along the high road to Whitechurch, near Dublin, and there were plenty of them on the spot.

Food.—*Agriolimax agrestis* is very voracious and omnivorous, but I think green food is preferred. In captivity they seemed to relish anything they were offered, and in this respect they are very different from most other slugs. In the garden I found them chiefly injurious to peas. They will eat the young shoots and the flowers, and even devour the pods. I doubt whether they do much damage underground to bulbs, which are chiefly preyed upon by *Anallia carinata*.

General Distribution.—Great Britain, and throughout continental Europe, Asia Minor, Persia, Siberia (?), Japan, Iceland, Greenland, the Azores, Madeira, Marocco. It has probably been introduced on the east coast of N. America, in Brazil, South Africa, and New Zealand.
Agriolimax laevis, Müller.


(Plate LVI., fig. 7.)

Body of a purplish brown colour. Mantle about one-half the length of body. Slime watery. Intestine without a cæcum.

External Characters.—This slug has not been recorded before from Ireland. It was discovered by Mr. Rathborne in Lord Massy’s estate at Killakee, near Dublin, and brought to me for identification. I shortly after found two additional specimens in the same place, *i.e.* along the banks of an old fish pond. Unfortunately none of the specimens were full grown, but I at once distinguished it, as I had expected to find it before, it having a very wide distribution, ranging all over Europe and America.

The best description which I have seen of this slug is that by Heynemann (14). According to him *A. laevis* differs chiefly from the closely allied *A. agrestis* by the size of the mantle, which is almost one-half the total length. The back is only very slightly keeled towards the end of the body, which is of a dark purplish brown colour throughout. Simroth states that younger specimens are of a dark gray, but those I found which only measured 3 mm. and 10 mm. respectively were precisely the same in colour as the largest which measured 15 mm. Its maximum length, according to Heynemann, never exceeds 20 mm. (about three-quarters of an inch), so that it is the smallest of our native slugs. The neck can be stretched out very considerably. The mucus is perfectly clear and transparent, by which the species can perhaps most easily be recognized.

The shell, especially in younger specimens, is often visible through the mantle, and its outlines are indicated by a golden yellowish colour.

Anatomy (Plate LVII., fig. 29).—All the specimens I found being immature, the reproductive organs were not fully developed. The intestine is similar to that in the last species, but the cæcum is entirely wanting. The largest specimen, measuring 15 mm., which I dissected, had only the female reproductive organs developed. This agrees with Simroth’s (38) observations, who found that the female portion of the generative organs was generally developed before the male portion. The hermaphrodite gland (*hg.*) is dark, the rest of the reproductive organ being much the same as in *A. agrestis*, with the exception perhaps of the penis, which, according to Simroth is hammer-shaped, the flagellum being of a very different shape from that in *A. agrestis* (32 Plate ix., fig. 17).
Reproduction.—I have not observed the eggs of this slug. Simroth (38) tells us that they are about the same size as those of *A. agrestis*, measuring between 1·25 mm. and 2 mm. in diameter. Moquin-Tandon (26) states that in *Limax brunneus* Drap (=*A. laevis*) the eggs are $1\frac{1}{4}$ mm. long and 1 mm. broad, and that the number at each deposition varies from twelve to eighteen. Simroth found young at all seasons, but does not give an opinion as to the limits of age in this species, and my own observations are so limited that I cannot venture to express an opinion.

Habitat and Food.—In Ireland this species seems to be very local, and it certainly never occurred to me in company with *A. agrestis*. In Germany it is found along with *A. agrestis* in the garden and field, but everywhere it appears to prefer damp situations, being commonest near banks of rivers or in ditches.

Mr. Burbidge, of the Trinity College Botanic Gardens in Dublin, mentioned to me quite recently that a little black slug had appeared in his orchid houses. I managed to secure a specimen, and found it to be an *Agriolimax laevis*, and I ascertained that the sphagnum moss so extensively used in the cultivation of orchids was brought down to Dublin from the neighbourhood of Killakee, the only locality where I have met with this species.* It seems to thrive in the warm orchid house, and manages to do a good deal of damage to the delicate flowers. I have not been able to ascertain what food it lives on in its original home.

General Distribution.—Great Britain, and throughout continental Europe; Siberia, and throughout North America and Brazil.

Genus III.—*Amalia* (Moquin-Tandon, 1855.)

Animal generally sharply keeled along the whole of body behind mantle. Mantle, which is shagreened or granulated, has a horse-shoe shaped groove. Body without bands. Pulmonary opening behind middle of mantle. Genital opening near base of tentacles. Intestine has four convolutions, and there are accessory glands in connexion with oviduct or vestibule. There is a solid internal shell, but no caudal gland.

This genus, like that of *Agriolimax*, has formerly been united with the genus *Limax*, and the various species of *Amalia* are found under the latter genus in such text books as Jeffreys (16) and Forbes and Hanley (9). In recent years the structure of slugs and their habits having become better understood, mostly owing to the labours of Simroth and of Lessona and Pollonera, the grouping under one genus of a number of miscellaneous forms has been discontinued.

Externally the Irish species are characterized by a sharp ridge or keel running along the whole of the back. In some of the Continental forms this keel does not seem to form such a prominent feature. A character which is applicable

*Since writing the above, I found this slug also in Connemara, county Galway, and at Killarney, county Kerry.*
to all the species and by which the genus is most readily distinguished from others, is the deep horse-shoe shaped groove on the mantle. The mantle, moreover, is different from that in the two preceding genera in being granulated.

As regards the internal organization, the genus is more closely allied to *Agriolimax* than to *Limax*, but still there are many very important differences. There are four convolutions to the intestine in both genera, but *Amalia* has accessory glands in connexion with the vestibule or oviduct, which are absent in *Agriolimax*. On the other hand, the penis in *Amalia* has no accessory gland or flagellum. The sperm is transmitted by means of a spermatophore in *Amalia*, and by a soft mucous capsule (Schleimpatrone) in the other. *Agriolimax* is quick in its movements, has a delicate skin and abundant liquid mucus, whilst *Amalia* is slow, with thicker skin and often with tough viscid mucus.

**Synopsis of the Irish Species of Amalia.**

I.—Colour generally brown, foot yellowish, and mucus viscid = *A. carinata*.
II.—Colour generally black, foot white, and mucus watery = *A. gagates*.

*Amlia carinata*, Leach.


(Plate LVI., fig. 8.)

Colour of body generally brown. Groove on mantle almost always filled with dark pigment. Skin thick, and interstices between wrinkles filled with black pigment, and slime viscid. Keel of a lighter colour than rest of body. Foot yellowish. Receptaculum seminis very large and elongated.

**Synonymy.**—The name *Limax marginatus* applied to this slug by Jeffreys (16) has already been disposed of, having evidently been intended by Müller (28) for quite a different species. The name *L. marginatus* has been kept up by Taylor and Roebuck (42) in their Irish list, and in the *Conchological Journal* (41), but it has been discontinued for the British form by Continental authors, such as Simroth (38) and Lessona and Pollonera (21). I think there is no doubt that the Irish form is the one described by Leach (19) as *Limax carinatus*. I was not sure whether it was the same as the Continental, at least the German form, so I submitted specimens of several varieties to Dr. Simroth, who pronounced them to be *Amalia carinata*, Risso. He tells me they differ but little from the German specimens, hardly sufficiently to attach to them a distinct varietal name. The proofs of Leach's work (19) were in circulation in 1820, so that his name should be attached in preference to that of Risso.
External Characters.—*A. carinata* is at once distinguished from all the preceding species by the prominent ridge or keel running from the posterior margin of the mantle to the end of the body. A less conspicuous feature, by which this and the next species may be distinguished from all others, is the horse-shoe shaped groove on the mantle. In *A. carinata* this groove is almost always filled with a black pigment, so as to render it more readily visible than in the next species. Some authors have thought it advisable to create a separate name for specimens in which the black marking meets in front to form a complete horse-shoe. However, I have examined a large number of specimens from gardens in Dublin where it is, after *Agriolimax agrestis*, the commonest slug, and I found that in fully 20 per cent. the horse-shoe marking is complete, i.e. unites in front. In some specimens there was only a faint indication of any marking at all; in fact, it is a feature which is not by any means constant. I noticed also that in those 20 per cent. in which the black pigment extends all round the groove, the general body-colour is darker than in the others.

The body-colour in this species varies from yellowish brown to dark brown, the sides getting lighter towards the foot. The inter-space between the wrinkles is generally marked by darker pigment, and the mantle is granulated. The head and tentacles are of a bluish colour, sometimes purple, and the keel is almost always lighter than the body-colour on each side of it.

The largest specimen taken measured 65 mm. long, by 10 mm. broad. Moquin-Tandon’s (26) *Limax marginatus*, which is probably this species, never exceeds 60 mm. in length in France.

Anatomy (Plate LVII., fig. 30).—There are the four convolutions of the intestine as in *Agriolimax*, but without a cœcum. The upper portion of the reproductive organs are like those of *Agriolimax*, but in the lower parts, important differences appear. The receptaculum seminis (rec.) is very large, equalling the free oviduct (ov.) in length. Its lower part is wide, but it becomes attenuated in its upper portion. What appears to be the penis is in reality the portion of the sperm-duct in which the spermatophore is formed (pat.); the lower portion only can be looked upon as a penis (p.). Both penis and oviduct, as well as the receptaculum, open into a short vestibule or atrium (lv.) which, according to Simroth (38), is everted during copulation. A number of large accessory glands (ac.) also open into the vestibule by means of delicate ducts.

Reproduction.—The fact that hardly any of the text-books referred to, give a description of the eggs of this species shows that they have rarely been observed. Although I kept a large number of specimens in captivity from the middle of September to the end of the year, none of them deposited eggs. Simroth (38) is the only author who refers to the ova of *Amalia marginata*, which is either the same or a closely allied species to ours. He states having observed them at the end
of March, and that they measure 6 mm. by 5 mm. They are, therefore, about the size of those of *L. maximus*, and very much larger than one would expect. I have met with a good many specimens of the slug, about 15–20 mm. long in July, so that the deposition of eggs in Ireland probably takes place in April or May. The young ones do not differ to any appreciable degree from the adults. I saw no half-grown or young specimens during winter, so that at any rate the reproduction of this form seems to differ from that of most other slugs, and in all probability it lives for more than one year.

_Habitat._—Simroth gives limestone rubble (kalkgeröll) in mountainous districts as the abode of the _A. marginata_. The habitat of our _A. carinata_ is totally different. It is one of the commonest garden slugs in Dublin. It is very gregarious, and one often finds a number of them close together in worm-burrows, or at the root of delicate plants. They are, like all slugs, fond of stiff clay soil, which keeps the moisture so much longer than sandy soil, and which, owing to the numerous worm-burrows, gives them better shelter. They spend the day underground, and come out at night in damp weather, but they often drag bits of stalks underground to feed on at their leisure. In the open country I have met with them everywhere, but only locally. They are widely distributed. Miss Warren tells me that this species is rare in Sligo, whilst _A. gagates_ is common, but I have received a large number of _A. carinata_ (rather dark ones) from the Aran Islands, county Galway, and it probably occurs everywhere in the West. These did not differ anatomically from our Eastern forms. It seems surprising that Clarke (3), who was such an authority on slugs, did not meet with this species in the North of Ireland, and only records it from Dublin, whilst Thompson (43) gives Monivea and Clifden in county Galway, and Cork, as the localities where it occurred to him.

_Food._—Simroth (38) believes that the German species of _Amalia_ are carnivorous. Although the Irish _A. carinata_ is carnivorous at certain times, it is generally a most determined vegetable feeder, and, I believe, runs _Agriolimax agrestis_ very close in being the most voracious and destructive of slugs.

As I mentioned before, I have had specimens in captivity for several months, and I have had good opportunities for observing its habits in the garden. I find that it is especially fond of leaf stalks and bulbs, but it greedily devours green leaves. The bulbs and stalks seem to suit them better when they are stale and beginning to decay. Of the thirty or forty which I kept in a large tin box filled with earth, and always supplied with leaves, bulbs, &c., about a dozen were eaten by their companions, only the shells being left. Observing them very closely, I noticed that only weak specimens, which seemed either old or seized by illness, were devoured.

The more vigorous ones always spent the day underground, burying themselves several inches deep. In the garden I noticed that many bulbs in heavy soil
entirely disappear. This would be commonly attributed to the nature of the soil, but it is really due to the depredations of *A. carinata*. I find that in sandy soil bulbs are less liable to be attacked by this species. Gain (10) states that *A. marginata* (= *carinata*) took most of the different kinds of foods offered. I hope this writer will publish a more detailed account of the nature of the food offered than what has hitherto appeared.

**General Distribution.**—Great Britain, Germany, Switzerland, France, Austro-Hungary, Greece, Italy, Spain, and Portugal.

**Amalia gagates**, Drap.


(Plate LVI., fig. 9.)

Colour generally dark lead or light drab brown. Keel of nearly the same colour as the rest of body. Interspaces between wrinkles and groove on mantle without black pigment; foot white, and slime watery. Receptaculum short and round.

**External Characters.**—As I have stated in the synopsis, this slug is distinguished from *A. carinata* by its colour, which is black, or, more correctly, dark lead. There is also a brown variety, but even then the two species are readily distinguishable. In *A. carinata* the brown is always richer, being either a deep rich brown or a bright yellow-brown, while in the variety of *A. gagates* it is always a light drab-brown. Besides, the foot is always pure white, the skin delicate, and the mucus watery. In *A. carinata* the foot is yellowish, the skin is thick, and the mucus tough and sticky. Both species may be distinguished merely by the touch. Whilst *A. carinata* feels like a sticky lump of fat, *A. gagates*, owing to its more watery mucus, glides readily through the fingers.

In this species the horse-shoe shaped groove on the mantle is well marked, but there being no black pigment, it is not so apparent as in the preceding one.

The mantle in *A. gagates* is almost of the same size as the body, whilst in *A. carinata* it is only about three-fourths of the length. The keel in *A. gagates* is much sharper than in *A. carinata*, and the interspaces between the body-wrinkles have no black pigment, which in *A. carinata* gives it the speckled appearance.

The largest specimen I have seen measured 50 mm. by 6 mm., showing that it is altogether smaller and more slender than the other *Amalia*.

**Anatomy** (Plate LVII., fig. 31).—Full-grown specimens measure about 30 mm. in
spirit. The various parts of the reproductive organs differ from those in *A. carinata*, chiefly in being much shorter. The sperm-duct (*sp.*), the "Patronenstrecke" (*pat.*), and the receptaculum (*rec.*) are all shorter, in comparison with the same organs in the preceding species. The receptaculum seminis (*rec.*) exhibits, perhaps, the most striking difference, being more rounded, with a short stalk. There is generally one accessory gland (*ac.*) opening into the vestibule, but sometimes there are more. I have noticed in a brown specimen as many as four, whilst in another from the same locality there was only one.

**Reproduction.**—The smallest specimens I have seen measured about 20 mm., and did not differ very materially in colour from the adults. A specimen kept in captivity deposited eight eggs at the end of August. They were very delicate and thin-shelled, adhering together by a glutinous mucus. They were slightly oval in shape, and measured only 2 mm. long by 1½ mm. broad. It is surprising that there should be such a very great discrepancy between the size of the eggs in the two species of *Amalia*.

**Habitat.**—This species is one of the rarest of slugs; and I never found it but in the open country, and only at all abundant in one spot, at Raheny, near Dublin, in a field under heaps of decayed weeds. In the same place I obtained an occasional specimen of the drab-coloured variety among the others. Later on I found a few specimens at Kilruddery and Whitechurch, both near Dublin. I received two specimens from Miss Warren, who found them in her garden at Ballina, in Sligo; and a dark one from the Aran Islands, along with a number of *A. carinata*. Clarke (3), who first discovered this species in Ireland, states that in the Queen's County, at La Bergerie, the brown variety is much commoner than the black. He has taken the slug also in the counties of Galway and Mayo, it being very abundant in the latter.*

**Food.**—Gain (10) states that this species took 83 per cent. of the different kinds of food which were offered. I have not myself observed what it lived on, but it seems probable that its chief natural diet consists in decaying plants.

**General Distribution.**—Great Britain, France, Italy, Spain, Portugal, Sicily, Sardinia, the Balearic Isles, Egypt, Algiers, Morocco, the Azores, Madeira, St. Helena, Ascension, South Africa (?), California (?), Bermuda, and, probably introduced, in Brazil.

**Genus IV.**—*Arion* (Férussac, 1819).

Body, nearly cylindrical, strongly wrinkled. Mantle, shagreened or granulate. There is a caudal gland. Internal shell, not solid, but composed of a soft mass of granules. Pulmonary opening in front of middle of mantle, and genital pore

* I have since taken it at Queenstown, county-Cork.
situated close to it. There never is a well-marked keel except in young specimens. The intestine has four convolutions.

The most apparent characteristic by which this genus may be distinguished from the preceding ones are the presence of a caudal gland, and the fact of the respiratory opening being situated in front of the middle of the mantle.

The caudal gland is easily visible externally (Plate LVI., fig. 10). Its opening is situated at the very end of the body, and is triangular in shape; the base of the triangle being directed towards the head.

Another, perhaps, less noticeable feature is that of the reproductive pore, which lies quite close to the respiratory opening, whilst we have seen that in the other genera it is situated near the tentacles.

The mantle, or shield, in Arion is granulated as in the genus Amalia.

All the species of Arion are altogether broader in shape than any of the slugs hitherto considered.

There never is, in Arion, a well-marked keel, and though we may, as in young Arion hortensis and A. bourguignathi, have slight indications of one, it is nothing like what obtains in Limax, Agriolimax, or Amalia. The wrinkles are generally more prominent in Arion than in the other genera.

As regards the internal structure of the genus Arion, I may mention in the first place that there is no solid shell, but a soft mass of calcareous granules, which, in some of the smaller species, may be somewhat firmer than in the larger ones. Simroth (38) has pointed out, that whilst Limax, Agriolimax, and Amalia utilize their male end-organs during copulation, in Arion the female end-portions of the reproductive organs are used as penes. What is generally looked upon as the penis in Arion is no such thing, there being no retractor muscle to it. The enlarged end portion of the sperm-duct is used for the preparation of the spermatophore (sperm-case), and Simroth (38) has applied to it the term "Patronenstrecke" (cartridge-portion).

There are four convolutions in the intestine, the first being the largest.

Synopsis of the Irish Species of Arion.*

A.—Margin of foot with transverse striae = A. ater, A. subfuscus.

I.—Wrinkles keeled and elongated = A. ater.

II.—Wrinkles flat and short = A. subfuscus.

* It is very difficult to give good external distinctions for the species of Arion, but the above will be found fairly practical, if it be kept in mind that wrinkles are a variable feature and that slugs must be compared under similar atmospheric conditions.
B.—Margin of foot without transverse striae = *A. hortensis*, *A. bourguignati*, *A. intermedius*.

I.—Foot coloured = *A. hortensis*, *A. intermedius*.
   a. Wrinkles flat = *A. hortensis*.
   b. Wrinkles with conical spikes = *A. intermedius*.

II.—Foot white = *A. bourguignati*.

**Arion ater, L.**


(Plate LVI., figs. 10–16).

Colour very variable, but generally either brown, black, or red, in adults; and either light red or yellow in young ones; wrinkles very long behind middle of mantle, and sharply keeled. Foot generally yellowish, but never white; head and tentacles dark violet.

**Synonymy.**—Many Continental authors have adopted for this species Férussac's (8) name of *A. empiricorum*, chosen by him because he thought a new name would avoid the confusion arising from Linné's adoption of two designations, viz. "*ater*" and "*rufus*" for varieties of the same species. According to the British Association Code of Rules, however, which is observed by British zoologists, the oldest name or the one standing first on a list shall be used, irrespective of the suitability of the name.

**External Characters.**—This species is the most variable of our Irish slugs. During youth the number of variations are much larger than in adults, as they almost all darken with age, becoming more uniform in colour.

In Ireland I have up to now met with six very distinct varieties of the adult slug, viz. brown, black, claret-red, salmon-red, olive, and black with yellow sides. In some of these the foot may remain unaffected by the colour, whilst in others the foot becomes more or less coloured too, but I think that is not a point of any importance. The brown variety (Plate LVI., fig. 10) is perhaps the commonest (in the gardens about Dublin, at any rate).

The margin of the foot, in all these varieties, is transversely striated, by which character this slug may be distinguished from all other species of *Arion* except *A. subfuscus*.

The wrinkles are useful in discriminating between *A. ater* and *A. subfuscus*. 
In the former the wrinkles on the back, just behind the mantle, are very long, and sharply keeled, whilst in *A. subfuscus* they are hardly half as long, and flat.

Too much importance, however, should not be attached to the shape of the wrinkles. Anyone who has kept this species in captivity can see for himself that, by carefully sprinkling the box in which the specimens are confined with water, the body-wrinkles after a while become more and more flattened out. A specimen which may have had all its wrinkles standing out sharply from the body, in a dry atmosphere, appears quite changed after it has been imprisoned in a damp tin box for a couple of hours. There are naturalists who have manufactured new species of *Arion* merely by the different shapes of the wrinkles; but a little practical observation shows how much they are worth. An adult of *A. ater* cannot be mistaken for *A. subfuscus*, but a young one might, and indeed has been by most writers. A rough and ready method of discriminating between the two species is to give them a tap on the head. *A. ater* will almost immediately draw itself together, and resting on its foot, the arched body will appear nearly equal in length and breadth (Plate LVII., fig. 11). Another tap now will, in almost every case, even in very young specimens, cause the animal to rock about from side to side. This most peculiar motion, which is often continued for several minutes, has never, to my knowledge, been observed in any other slug. A similar tap applied to *A. subfuscus* will merely cause the animal to shrink up, but it will never assume the characteristic hunched position of *A. ater*, nor will any tapping produce the swaying movement.

The margin of the foot is very often of a colour different from the rest of the body; thus in brown specimens the margin may be brick-red. On the Continent specimens of a similar brick-red tint covering the whole body are extremely common, and in central Europe the large majority are of this colour. (This will be referred to again in the Chapter on Colour.) I have never seen an adult brick-red specimen in Ireland.

The head and tentacles are, as a rule, of a dark violet colour. There is no trace of a keel, the back being perfectly rounded.

This species assumes much larger proportions on the Continent than it does in Ireland. The largest I have seen near Dublin measured 90 mm. by 10 mm. On the West Coast specimens of that length, but rather broader, are common. The average size for a full-grown specimen on the East Coast, however, is 60 mm. by 10 mm.

The nature of the mucus varies in proportion to the severity of the stimulus. As a rule colourless, it becomes orange-yellow when the animal is much irritated, and sometimes I have seen it milky like that of *Agriolimax agrestis*.

*Anatomy* (Plate LVII., fig. 32).—Detailed accounts of the anatomy of this species have been given by Lawson (18), Nunneley (31), and others. I have
examined specimens from Norway and the different parts of Ireland, and find that there is less difference between the East Irish and Norwegian than there is between the West and East Irish.

The colour of the hermaphrodite gland (hv.), generally of a light brown, varies according to the colour of the body. The hermaphrodite duct (hd.) is well convoluted. The free oviduct (ov.) opens into a vestibule as in Amalia, but there is in Arion ater an additional glandular lower vestibule (lv.) which has by Lawson (18) been incorrectly named cloaca. The upper vestibule (uv.) or atrium he distinguishes as the "egg-sac."

The sperm-duct (sp.) ends in what used to be regarded as a penis, but which Simroth (38) has shown is only the enlarged lower portion of the sperm-duct (sp.) in which the spermatophores or sperm-cases are formed. The receptaculum (rec.) and the "Patronenstrecke" (pat.) of the sperm-duct (sp.) opens into the lower portion of the upper vestibule (uv.).

Both the oviduct (ov.) and the duct of the receptaculum are provided with powerful retractor muscles (rm.), which in West Coast specimens are attached quite close to the receptaculum and the upper portion of the oviduct, respectively, whilst in East Coast forms these same muscles are almost invariably attached much lower down to the same structures. Of course this alone may not be of much importance, but coupled as it is with differences in colour and length of life, the West Coast forms constitute what we may at present regard as a striking variety of A. ater which may become further modified in time. I propose to reinvestigate this form when I have collected more material in the West.

Reproduction.—The eggs are laid chiefly in August and September, in clusters averaging about fifty in number. I have frequently observed them in fields under heaps of hay and in gardens under stones. They are deposited freely in captivity. They adhere only very slightly to one another, and may be easily distinguished from any of those previously described by their remarkable hardness. They feel quite solid, and owing to their calcareous shells are perfectly opaque. They have a long diameter of 4 mm. and a short one of 3 mm.

I said above that reproduction takes place chiefly in August and September, but a few specimens, undoubtedly, deposit eggs earlier, for I have seen quite young ones in August, and as the eggs take about 4 to 6 weeks to develop, they must have been deposited in June.

Throughout the winter large numbers of young ones are to be met with in the garden, and frost does not seem to affect them very much. These young specimens (figs. 13 and 14) are invariably of a very light yellow or red—never dark. Generally well-defined black lateral bands run along each side of the body, and are continued on the mantle, ending at its anterior margin; and all have dark-coloured heads and tentacles. I have no doubt that these young forms, which are
about 30 mm. long in March, reach their maturity in the following autumn, and I quite agree with Simroth (38), who fixes the limit of age in A. *ater* at one year.

In the month of March the portion of the back and mantle between the lateral bands becomes darker, a condition which is well seen in figs. 11 and 12; and in that case a narrow light stripe is left between the dark portion and the bands. But in some cases the back darkens uniformly, producing forms which have been described by Roebuck as var. bicolor (fig. 15). I have found a half-grown form at Whitechurch, near Dublin, in which the back remained light, whilst the sides darkened (fig. 16). Similar young forms of the var. bicolor have been described by Simroth (38) from the shores of the Baltic, and it is remarkable that every instance of their occurrence is in close proximity to the sea. The light sides in these specimens remain light throughout life. At Raheny, near Dublin, where I have collected extensively last September, fully 30 per cent. were black above with yellow sides, the remainder being entirely black with olive margin of foot. All these had fully-developed reproductive organs. At Howth, Mr. Redding has taken them with brilliant orange sides (fig. 15). In both cases the specimens were found almost within reach of high tide. Only in one instance have I seen this variety further inland in several specimens which were kindly given to me by Mr. A. G. More, from his garden at Rathmines. This lies fully three miles from the sea, but it may be that they found their way to the gardens with plants from the sea-side.

This disposes of the *A. ater* from the East Coast of Ireland. On the West Coast the same species forms a very remarkable variety, possibly owing to the difference of the meteorological conditions. If we look at Scott’s (37) latest report on the variability of the temperature in the British Isles, we find that during fifteen years in Valentia Island, the thermometer only descended below freezing point six times. In summer, during the same period, it only once rose above 70° F. (= 21° C.). There is in fact probably no place in Europe where such an equable climate exists as on the South-West Coast of Ireland.

As a result of these favourable meteorological conditions, adult forms of *A. ater* survive the winter, but apparently do not develop reproductive organs in that period. I received a large box of specimens, 80 mm. long, from the Aran Islands in November. Their body cavity was almost entirely filled with a huge liver and intestines, whilst the generative organs were like those of an ordinary half-grown specimen. Again, in May, I collected everywhere in the mainland of Kerry, and on Valentia Island, numbers of specimens considerably larger than our Dublin full-grown forms, but again with hardly a trace of any reproductive organ. Among these an olive-coloured variety is very common, and also one of a cinnamon-red; neither of these is banded. Besides these, rich brown forms, like
those on the East Coast, also occur. Those from the Aran Islands were almost all pitch black.

I only found two specimens with fully developed reproductive organs in my collection, and these were sent to me in August by the Rev. A. H. Delap, from the Skelligs Rock, off Valentia. Thus we probably have the same period of reproduction as on the East Coast, but the specimens either live for two years, or for a year and a-half. The latter seems to me more probable, and we should, in that case, have a second period of reproduction in the early months of spring on the West Coast.

Habitat.—This species is found everywhere in company with Agriolimax agrestis, both on the mainland and many of the islands on the West Coast. In the garden it is one of the commonest forms. In my own garden I have never seen an adult of any other colour than a rich brown (fig. 10). Similar brown slugs I have noticed as very abundant on the West Coast. In woods and fields near Dublin I have hardly ever seen this variety. In the Dublin Mountains, at Killakee, all the adult forms I obtained were of a dark claret colour; they resembled very much the fallen pine-needles that covered the ground, and it seemed to me a case of protective colouring.

On the West Coast I have collected at Cahirciveen, Derrynane Bay, and other places in the Co. Kerry, and most specimens were either brown or olive-coloured—sometimes of a salmon-red—and the ground being boggy, again resembled the colour of the slugs. It has been remarked by many observers, and it agrees with my experience, that this slug is more often seen crawling about in the daytime than others. I have especially noticed this fact on the West Coast, where, of course, the climate is exceedingly damp, but it struck me also in the forests of Germany, where one sees so many large red-coloured A. ater.

Food.—A. ater is undoubtedly a voracious vegetable feeder, preferring decaying chlorophyllaceous plants to fresh ones. I have kept them on campanula leaves for a long time. Kew (17) kept this species in captivity from May to October, during which time twenty-six different substances were eaten. One slug lived on a newspaper for some time. He says—"The dead bodies of Avion subfuscus, A. hortensis, Límex maximus, L. flavus, and L. agrestis, a dead Unio, freshly turned pupae of Adimonia tanaecí, a small part of the abdomen of a dragon-fly (Diplax striolata), leaves of lettuce, Scabiosa succisa and Solanum nigrum, flowers of Pedicularis sylvatica, Ranunculus flammula, R. acris, R. repens and R. bulbosus, and the lichens Evernia prunastri and Ramalina farinacea were readily fed upon. Poly- podium vulgare, Eryngium maritimum, and berries of Arum maculatum were taken in small quantities and with evident reluctance, as also was Pears' soap."

Thompson (43) noticed two specimens of this species busily engaged devouring a snail (H. aspersa) which appeared to be freshly killed.
We thus see that although *A. ater* is on the whole a vegetable feeder, it is not particular as to its choice of food, and is always ready to eat almost anything that comes within reach.

**General Distribution.**—Great Britain, and throughout continental Europe, Algiers (?), Azores (?), Madeira, and Iceland.

*Arion subfuscus*, Drap.


(Plate LVI., figs. 17–19.)

Colour either yellowish or light gray; never brown or black. The wrinkles short and flat. Margin of foot white, with gray transverse striae. Thick yellow slime on body, chiefly near head and tail. Foot and sides of body generally white; sometimes yellowish.

**Synonomy.**—In such text-books as Jeffreys (16) and Forbes and Hanley (9) this species is grouped under the varieties of *A. ater*, although it had long before been described as a distinct form by Draparanaud (5). I believe that Müller's (28) *A. flavus* is an immature form of *A. subfuscus*, and not identical with Simroth's (38) *A. minimus*, the latter never growing longer than one inch, whilst Müller gives 1¼ inch as the size of his slug.

**External Characters.**—Three varieties of this slug are found near Dublin which, although they do not, as far as I have been able to ascertain, differ anatomically, show considerable external differences. We may, indeed, regard them as species in process of formation. I have had too few specimens to come to a definite conclusion, and further researches may reveal new characters by which they can be separated anatomically.

The typical *A. subfuscus* (Plate LVI., fig. 17) resembles *A. ater* in having the margin of the foot transversely striated, and in having a dark head and tentacles, which, however, are never as dark as those in *A. ater*. The sides are white, and have a semi-transparent appearance like a wax candle. The margin of the foot, and the foot itself is white, the former with delicate gray cross-bars. There is no variety of *A. ater* with a white foot or white sides, and this distinguishes the typical *A. subfuscus* at once. The upper surface is dark gray, becoming lighter towards the very distinct lateral bands. The whole of the back and mantle is almost always covered to such an extent by a thick reddish-yellow mucus, as to obscure the gray colour and make it appear reddish-brown. The mucus is most intense in colour on the anterior portion of the mantle, and near the caudal gland.
To show that this mucus has nothing to do with the real colour of the slug one need only wrap it up in a piece of blotting paper, and roll it about for a moment, when all the mucus will be soaked up. The slug then appears in his natural costume, which is composed of white and a bluish-gray, without any trace of a yellow or red pigment in the skin.

If we subject the two varieties (Plate LVI., figs. 18 and 19) to the same treatment we get a very different result. The first (fig. 18), which, by the way, is not the A. brunneus mentioned by Lehmann (20) and Simroth (38), has no lateral bands, but is rather darker on the back than at the sides. It is a yellow slug, but on the mantle we again find the peculiar reddish mucus, and if the latter is soaked up by blotting paper, we have an entirely yellow slug, and the yellow is due to a pigment investing the skin in small granules. Moreover, the space between the wrinkles is of a bluish colour. The second variety (fig. 19) is entirely yellow, with a lateral band on the back. The margin of the foot in both these varieties is yellow, the yellow colour extending also to one-third the breadth of the foot on each side.

I found the typical form of A. subfuscus generally between 40 and 45 mm. in length, whilst adults of the first variety were as a rule rather smaller, viz. 35 to 40 mm. Of the second variety I obtained only one specimen, whose reproductive organs, although not fully developed, showed that it was more nearly allied to A. subfuscus than to A. ater. Recent investigations into the anatomy of the Arionidae such as those of Pollonera (33) and Simroth (40) may throw light on the affinities of this species, which for the present I must regard as a variety of A. subfuscus more material is available. My specimen was 55 mm. in length.

The wrinkles in all these slugs differ from those in A. ater in being much shorter, which is especially well seen in the wrinkles just behind the mantle. They are much flatter than those in A. ater, although one has to guard against the influences of temperature in comparing these in different slugs, as I have had occasion to point out under the heading of A. ater. The slime is abundant and clear, and must be distinguished from the intensely yellow mucus which is until produced by the mucus glands on the back and mantle of the slug.

Anatomy (Plate LVII., fig. 33).—The internal organization of this species differs little from that in A. ater, but all the different parts, of course, are smaller. The ovisperm-duct (os.) is shorter in proportion than in A. ater. As in the latter there is no penis, the sperm-duct (sp.) ending in a “Patronenstrecke” (pat.) in which the spermatophores are produced. This portion opens into the lower part of the duct of the receptaculum (rec.), which, in its turn, opens directly into a lower glandular vestibule (lv.), the upper vestibule being absent. The genital retractor muscle (rm.) is attached to the oviduct (ov.) much higher up than in A. ater (see fig. 32).
Reproduction.—I found the eggs of the typical *A. subfuscus* commonly at Raheny, near Dublin, at the end of August, and the species also bred freely in captivity. The eggs were mostly about 3 mm. long by 2½ mm. broad, and semi-transparent, much clearer than those of *A. ater*. Similar eggs, but rather smaller, viz. 2½ mm. by 2 mm. were deposited in captivity by the variety shown in fig. 18. The eggs number generally about twenty in a cluster, and were seen from the middle of August to the middle of October. The young forms were not observed, and I have not sufficient data to express an opinion as to its limits of age.

Habitat.—I have taken the typical form of this species very abundantly at Raheny, Co. Dublin.* They were found in fields close to the sea where horses were kept and fungi abounded in autumn. Wherever there was any horse-manure, numbers of *A. subfuscus* were sure to be close by. But I also got them under decaying heaps of weeds in another field in the neighbourhood.

The difference between those found among the manure, and those occurring among the weeds, first drew my attention to the absence of yellow in the skin of these slugs, the colour being entirely due to the mucus. Those found among the weeds secreted hardly any of the yellow mucus, and being white with gray backs, differed at first sight very much from the vividly-coloured specimens found previously.

The first variety (fig. 18) was found in a small pine wood on Howth Hill, near Dublin, about 300 feet above the fields referred to. Similar specimens were obtained on Bray Head, in the Co. Wicklow, and, along with the variety fig. 19, at Killakee in the Dublin Mountains.

Food.—These slugs seem almost entirely to subsist on fungi, chiefly of the genus Russula; but they do not despise the poisonous *Agaricus muscarius*, which proves deadly to flies and other insects. I once observed two specimens eat a fallen poplar leaf in a wood, although plenty of fungi were quite close to them; but it was only after some days that specimens in captivity gnawed at the green leaves of Campanula. Simroth (38) found them, especially in the north of Germany, feeding on all kinds of fungi, and observes that they never colour spirit green, which proves that they do not live on chlorophyllaceous food.

Kew (17) saw *A. subfuscus* devour a dead specimen of its own species, and also an *Amandia marginata* (= *carinata*). In captivity, he observes, they eat bread and leaves of lettuce freely, also the leaves of *Solanum dulcamara* when decomposing. A fungus (*Phallus impudicus*) was eaten voraciously, but the slugs then died, probably owing to the foetid smell given off by it.

General Distribution.—Great Britain, continental Europe (except Spain and Portugal), Iceland, and Greenland (?).

* I also found it at Glengariff, Co. Kerry.
Arion hortensis, Férussac.


(Plate LVI., fig. 20.)

Colour of body generally dark gray or light brown, with bluish-gray sides. Lateral bands somewhat diffuse towards sides of body, always present, and continued to front of mantle. Foot always red, wrinkles broad. The calcareous grains composing shell often more aggregated than in other species. Receptaculum seminis round.

External Characters.—A typical form of this slug is at once recognized from other species by the red colour of the margin, as well as the sole, of the foot. But the intensity of this colour is subject to a good deal of variation, and in many cases the foot is more of a yellownish colour, with just a tinge of red, while sometimes only a faint indication of colouring remains. In such cases A. hortensis might well be mistaken for one of the other species. By a little practice, however, we can soon detect other distinguishing characters.

If we take an A. hortensis of 20 mm. in length, and compare it with specimens of A. ater (Pl. LVI., fig. 16) A. bourguignati (Pl. LVI., fig. 21), and A. intermedius (Plate LVI., fig. 22) of the same length, the little conical wrinkles will at once eliminate the latter. From A. ater the specimen of A. hortensis will be distinguished by its dark colour, young ones of the former being always light-coloured; the wrinkles, moreover, in A. ater are longer and broader. Sometimes A. hortensis is remarkably like A. bourguignati, but apart from the wrinkles, which are broader in the former, the lateral bands are somewhat diffuse towards the external edge, as if they had been touched by a wet brush, whilst in A. bourguignati their edges are well defined.

If spirit specimens of the same size are taken, which sometimes have lost all trace of colour, the wrinkles must decide, and, of course, as a last resource, the anatomy. If we measure the width of the wrinkles just behind the mantle, we find that in A. ater rather more than one, in A. hortensis two, and in A. bourguignati three wrinkles go to the millimetre.

So much for comparison. As for the general colour of this species, I find that two distinct varieties are as a rule found in the garden. The back of the body and mantle in the first is of a dark gray, becoming lighter towards the lateral bands. Below these the body is of a light, sometimes bluish-gray colour.

In the second variety, which was much more numerous in my garden in September, the back of body and the mantle were as if dusted over with fine yellowish
brown powder, so as to produce a light brown tint (Plate LVI., fig. 20). Below the lateral bands the body colour is a light brownish-gray.

According to Simroth (38) the light colour is produced by warmth, and the dark by cold; but whether this explanation holds good in the case of the two varieties of *A. hortensis* occurring in the same locality at the same time of year, seems to me extremely doubtful. However, I shall refer to this again in the chapter on colour.

The largest specimens of this species were 35 mm. long. The mucus is yellow and somewhat sticky.

**Anatomy** (Plate LVII., fig. 34).—As in the other species the characteristic part of the anatomy is to be found in the lower portion of the reproductive organ. As in *A. ater* there is an upper (uv.) as well as a lower vestibule (lv.). The free oviduct (ov.) is long and widened in its lower part. The sperm-duct (sp.) ends in a somewhat swollen "Patronenstrecke" (pat.), whilst the long-stalked receptaculum (rec.) is round. The genital retractor muscle (rm.) divides into two bundles, one going to the duct of the receptaculum, the other to the oviduct.

The calcareous grains under the mantle are, in this species, often aggregated so as to form a rudimentary shell, which, according to Lessona and Pollonera (21) in Italian specimens is well developed.

**Reproduction.**—I kept about fifty specimens in captivity from the middle of September to the end of October, but no deposition of ova took place, nor did I ever see ova that I could refer to this species. Simroth (38) had some eggs deposited by captive specimens, which were perfectly round and clear, with a diameter of 2 mm.

It is remarkable that very young specimens of this species have a keeled back, but this keel, not being different in colour from the surrounding wrinkles, is not very easily seen—and it entirely disappears in half-grown specimens.

It seems to me probable that the deposition of ova takes place in the early months of summer or spring, but additional observation is needed also with regard to the duration of life in this species. All the specimens I have seen during winter were pretty large, mostly half-grown, which leads me to suppose that no deposition of ova takes place during autumn.

**Habitat.**—Simroth (38) states that *A. hortensis* is a South European form, and probably does not occur north of the 52° of latitude. However, he has since examined the Irish forms, and pronounced them identical with the German ones, so that we may safely conclude that it does extend considerably farther north than Simroth anticipated.

The same author states that he has never met with a specimen anywhere but in gardens, churchyards, and within villages.

In Ireland, although also very common in gardens, it certainly has a wider
range. I have found it in a wood at Kilruddery, in Co. Wicklow; also at Killakee, in the Dublin Mountains, and other places far removed from cultivated ground.

It seemed to me remarkable never to meet with the brown, or yellowish variety in the open country—all were of a dark bluish-gray, and the foot always more yellowish than red.

Although I did not find this species in Kerry, Miss Warren kindly sent me half a dozen specimens from Sligo, and it has also been recorded by Thompson (43) from the North of Ireland.*

Food.—I had great difficulty in keeping this species in captivity, and its numbers diminished rapidly until they all died. Pieces of apple and Campanula leaves were eaten, but neither appeared to be relished; and I am inclined to think that *A. hortensis* lives chiefly on decaying vegetation, as they are most numerous in the garden among heaps of old weeds. I have never found it on fungi. Simroth (38) believes that it is a vegetable feeder, and that it is especially partial to heavy soil. Gain (10) also found that *A. hortensis* was rather sickly in confinement, but he states that 60 per cent. of the foods offered were taken.

General Distribution.—Great Britain and Continental Europe, except Scandinavia and Russia.

### Arion bourguignati, Mabille.


(Plate LVI., fig. 21.)


External Characters.—As I have pointed out above, this species is so much like *A. hortensis* that the two species are still by many conchologists mistaken for one another.

The brilliantly white foot is one of the best distinguishing characters, but by the mere touch one is often able to discriminate between the two forms, as *A. bourguignati* is always much less slimy. The wrinkles are narrower, and its whole appearance is more slender. Young specimens, as pointed out by Mabille (24), are at once recognized by the keel which, owing to its white colour is rather conspicuous. It is a somewhat smaller species than *A. hortensis*, the maximum length reaching as a rule not more than 32 mm.

* I have since found it in Wexford and Queenstown, in the South, and in Connemara, in the West of Ireland.
As in the other, there are two varieties in colour, but in the garden I have never met with the dark form. The young, both in the open country and garden, are delicately gray, with a well-defined lateral band on each side of the body and mantle. The colour remains the same in the garden forms as they grow up, but a number of reddish pigment spots appear, which produce a general effect of tangerine. In the country specimens I have never observed this development of red pigment, and the original gray colour merely darkens, so as to produce a dark-gray slug.

Anatomy (Plate LVII., fig. 35).—Although this and the preceding species are difficult to distinguish externally, anatomically A. bourguignati presents unmistakable characteristics.

The hermaphrodite gland (hg.) is dark-brown and round. The free oviduct (ov.) which is long in A. hortensis, is here quite short, whilst on the other hand, the sperm-duct (sp.) is longer in A. bourguignati, and the "Patronenstrecke" (pat.) is not swollen. But perhaps the most apparent difference between the two species is the shape of the receptaculum (ree.) which in this species terminates in a long pointed apex. A. bourguignati has only one large vestibule (lv.), viz. the lower, whilst in A. hortensis there are two.

Reproduction.—I have not been able to observe the deposition of eggs in this species, although large numbers of specimens were kept in confinement during the months of September and October.

This and the almost complete absence of adults in September lead me to think that reproduction takes place early in the summer. This agrees with Simroth's (38) observations, who also found only half-grown forms during winter.

Habitat.—This species is not nearly so common as the preceding one, but still it has a wide distribution in Europe. I have obtained it commonly in my garden where the soil is heavy, and also among moss and under stones in the Dublin Mountains. In Kerry I found it on Valentia Island and at Lough Caragh, whilst Miss Warren sent me a specimen from Ballina, in Sligo.

I met with the largest specimens in June and July, but never in the daytime. This, no doubt, accounts for the fact of its having been comparatively rarely met with on the Continent, for Simroth (38) states that it is rare during summer, whilst Mabille (24) speaks of it as "une espèce d'hiver."

Food.—Like the last, this species does not thrive in captivity, and although they will nibble at pieces of apple and rhubarb stalk, they appear to me to prefer decaying vegetation. I never found it among fungi, but in my garden, when it emerged from the ground early in the evening along with Agriolimax agrestis, it, as a rule, remained on the ground, whilst the latter ascended the ground, whilst the latter ascended the pea plants, and did a great deal of damage by eating the young shoots and flowers. It seemed to me
as if *A. Bourguignati* preferred to feed on the fallen flowers which were partially decomposed, instead of attacking the living parts of the plant.

Gain's (10) experience is very different from mine, for he says: “This slug ate exactly one-half of the foods given, and thrives and breeds freely in confinement.”

**General Distribution.**—Great Britain, and continental Europe, except Spain and Portugal, and Siberia (?).

**Arion intermedius**, Normand.


(Plate LVI., figs. 22, 23.)

Colour light yellow or gray, with abundant yellow slime chiefly near head and caudal gland. Wrinkles with little conical spikes. Lateral bands either absent or very faint. It occurs chiefly on fungi.

**Synonymy.**—Simroth (38) was the first to re-establish on anatomical grounds the claims of this form to rank as a distinct species. Finding no satisfactory description of any species corresponding to his own, he called it *Arion minimus*, which name I temporarily adopted in a preliminary notice sent to the Conchological Society (36). Since the publication of his monograph, Simroth consulted the writings of older authors, such as Müller (28) and Nielsson (29), but as their *A. flavus* seemed to have been a larger slug, probably a young *A. subfuscus*, he thought his name (*A. minimus*) should be retained. Gmelin (11) and Férussac (8) merely repeated Müller's description without apparently having seen the slug. Among Moquin-Tandon's (26) uncertain species, we find *A. flavus* again, and there is no doubt that the author of the “Mollusques terrestres et fluviales de France” really had specimens of our slug before him, which he believed was the same as that referred to by Müller, Gmelin, and Férussac. But as Pollonera (32) has pointed out, the priority rests with another French author, viz. Normand (30), who described the same species under the name of *A. intermedius* three years before him.

**External Characters.**—This is the smallest of our Arions, and the only one besides *A. ater* which when at rest assumes the peculiar arched position (fig. 23). When examined in that attitude with a pocket lens we find that the wrinkles project in the shape of little conical knobs, and these give the slug that glittering appearance by which it is easily recognized from the other species.

The colour of *A. intermedius* is almost always white, or sometimes light gray, but owing to an abundant yellow mucus it often appears canary-yellow, especially near the caudal gland. The foot also is yellow, due to the same cause. The head and tentacles are dark gray.
The bands are sometimes completely absent, but when present, they are very faintly marked and diffuse, both on the body and mantle. I think the nature of the lateral bands and the wrinkles are the two most characteristic features in this slug.

Compared with *A. Bourguignatii*, for which dark specimens might be mistaken, the touch alone will help us to some extent, *A. intermedius* being much softer, and leaving a bright yellow watery mucus behind, whilst the former is thick-skinned, with a sticky white mucus. The habitat will also distinguish the two species, as they are never found in company.

Anatomy (Plate LVII., fig. 36).—The reproductive organs, as has been shown by Simroth (38) approach those of *A. subfuscus* more than those of any other form.

The oviduct (*ov.*) is short and straight, the receptaculum seminis (*rec.*) round, and the sperm-duct (*sp.*) scarcely swollen in the “Patronenstrecke” (*pat*). These open into a large vestibule (*iv.*).

Reproduction.—The clusters of eggs which I observed very frequently in August and September never exceeded twenty. The eggs are remarkably large for the size of the slug, being 2 mm. long by 1½ mm. broad. The young ones of 8 mm. in length, which I bred in captivity, were of a light gray, owing to the intestine being visible through the semi-transparent walls of the body. The head was of a delicate gray, and no bands were visible on the body or mantle. Still younger ones, of 3 mm. long, were of a very light red, with violet tentacles, and had emerged from the egg three weeks after their deposition. Their limit of age has been determined by Simroth (38) as not exceeding one year. I myself found adults up to the middle of October, but not by any means so commonly as during August and September.

Habitat.—This slug is never met with in the garden or on cultivated ground. I found it for the first time last August in a field under a heap of decayed weeds at Raheny, near Dublin, in company with *Arion ater*, *A. subfuscus*, *Amalii gagates*, and *Agriolimax agrestis*. Shortly after, I obtained numerous specimens close by feeding on common mushrooms (*Agariicus*) and fungi, which had appeared in the fields.

In the Earl of Meath’s demesne at Kilruddery, county Wicklow, this slug is common; also at Killakee in the Dublin Mountains. In fact, wherever there are fungi one is sure to find it, but, like *A. subfuscus*, it takes green food pretty freely in captivity. No doubt, *A. intermedius* has a wide range, but up to the present I have only taken specimens in the neighbourhood of Dublin, whilst one was sent me by the Rev. A. H. Delap, from Lough Caragh, in Kerry. This latter was of a uniformly dark gray colour.*

Food.—The nature of the food has already been referred to above. *A. inter-

* I have since taken them in Connemara, in the West of Ireland.
medius is a most typical fungus-eating slug, and I have chiefly found them on species of Russula, Agaricus, and Clavaria.

General Distribution.—Great Britain, Scandinavia, Germany, France, Italy (?), and probably introduced in New Zealand.

Genus V. Geomalacus, Allman, 1846.

Body sub-cylindrical; pulmonary opening on front of middle of mantle. Genital pore near base of upper tentacles. Caudal gland opening by transverse slit. There is a solid internal shell.

This genus was established by Allman (1) to include the most interesting of Irish slugs.

At first sight a Geomalacus looks very much like an Arion, but the end of the body which in that genus is pointed, and contains the longitudinal opening of the caudal gland, is, in Geomalacus, rounded off, so that the caudal gland opens by a transverse slit between body and foot.

The reproductive pore or genital opening lies close to the tentacles, as in the genus Limax, whilst in Arion, as we have seen, it is situated near the pulmonary aperture.

As for the anatomy, the distinctive characters of Geomalacus maculosus will be mentioned below, so that it remains only to be said that there is a solid internal shell, something like that in Limax, but very different from the calcareous particles found in Arion. Only one species has hitherto been found in Ireland, and it occurs nowhere else in Europe, except in North-western Spain and North Portugal. Two other species of Geomalacus (G. oliveirae and anguiformis) have been found in Portugal, but only short descriptions of their external characters have appeared as yet.

Mabille (23) in a Paper on the genus Geomalacus, described several species of French slugs, which he believed to be of this genus, but it has already been clearly demonstrated by Heynemann (13) that this view is entirely without foundation. They really belong to the genus Arion.

Geomalacus maculosus, Allman.


(Plate LVI., fig. 24.)

Colour dark gray, with light yellow or whitish spots on body and mantle.

External Characters.—The figures given by Heynemann (13) in his excellent
Paper on this species, are much better than Allman's original drawings, in spite of the fact of the latter having been executed by so able a draughtsman as the late Mr. Du Noyer. Du Noyer's figures are pretty, but idealized. The only point in Heynemann's figures which I take exception to is the caudal portion of the body. This should not be so flat, but more raised as in my figure 24. Forbes and Hanley (9), Jeffreys (16), and others, seem to have merely copied Allman's figure.

This slug was discovered in the county Kerry, in the autumn of 1842, by the late William Andrews of Dublin, who placed it in the hands of Dr. Allman; and it was first exhibited at a meeting of the Dublin Natural History Society in January, 1843. The skin is always smooth and shiny, and not black, but of a dark gray colour.

Both on the mantle and back there are a series of yellowish-white or yellow spots. These seem at first sight quite irregularly placed on the body, but Simroth (39) has drawn attention to the fact that on closer inspection there appear traces of distinct longitudinal bands, as in *Arion*. In most cases, indeed, I have observed these very well, but in others the banding is very difficult to demonstrate. The margin as well as the sole of the foot are of a dirty white. The tips of the tentacles are cylindrical, whilst in the genus *Arion* they are round. The mucus is transparent and limpid. The largest specimen measured about 55 mm. in length.

Mabille (23), in his Paper on the genus *Geomalacus*, referred to on p. 551, has attempted to set up a second species, which he calls *G. andrewsi*. His assumption is based on Allman's original description, who mentions, besides the common form, a white-spotted variety. Mabille believed that this meant a white, spotted variety, *i.e.* a white slug with black spots, and, astounding as it may appear, proceeded on these grounds to describe it as a new species.

*Anatomy* (Plate LVII., fig. 37).—Heynemann (13) does not deal with the anatomy of this slug, excepting in a reference to the shell and the tongue, neither of which is of very great importance. The latter is very much like that of an ordinary *Arion*, but the shell is firm and regular like that of a *Limax*.

The fact that the calcareous particles often congregate together in *Arion intermedium*, and form a kind of irregular shell, has induced French authors, such as Mabille (23) and Baudon (2), to start the idea that this slug must be a *Geomalacus*; but the shell in the genuine *Geomalacus* is of a very different nature. The intestine resembles that of *Arion*, but the reproductive organs differ widely.

The penis (*p*) is formed by the enormously developed duct of the receptaculum seminis (*rec.), and not by the oviduct, as in *Arion*. There is a long retractor muscle (*rm.*) attached to the penis at the part where the sperm-duct opens into it. The sperm-duct (*sp.*) is very much longer than in any *Arion*, whilst the ovisperm-duct (*os.*) is shorter.
Reproduction.—I found a few half-grown specimens along with the adults last May, but did not observe the eggs. Dr. Simroth very kindly sent me the proof-sheet of his large Memoir on the Slugs of Portugal and the Azores (40), and in it I find a statement that a Signor de Silva e Castro had seen the eggs. They were quite transparent, and very large, measuring from 5 to 7 mm. long, and 3 mm. broad. Simroth obtained about 40 young ones at Las Caldas de Gerez, in Portugal.

Habitat.—The first living specimens I have seen were presented to me last April by Mr. A. G. More. They had been collected on the eastern shores of Lough Caragh, in county Kerry, the same locality where Andrews had originally discovered the slug.

In the following May, while returning home from the dredging expedition to the West Coast, organized by the Royal Dublin Society, I passed Lough Caragh, and spent a portion of the night in hunting for this interesting slug, but without success. The following morning I walked to the eastern shores of the lake, and although I turned over hundreds of stones, I discovered nothing but Linnax maximus, L. marginatus, and Arion ater. I was about to give up the search, when I noticed a young specimen concealed among the lichens which grow here so abundantly on the surface of the rocks, and, after a while, I found several others similarly exposed to the full rays of the sun, it being then about two o'clock in the afternoon.

The dark gray lichens, with the white or yellowish fructification, conceal the slug perfectly, and there is no doubt that we have here a most striking instance of protective colouring. Lough Caragh is situated close to the head of Dingle Bay, in County Kerry, and, up to quite recently, it was the only spot in Ireland where this slug had been found, but, during last autumn, Mr. Scully discovered it about twenty-five miles further south, on the Kenmare and Glengariff road.*

I notice in Simroth's (40) proof, referred to above, that he found this species among lichens at the foot of a granite wall in the province of Minho, in Northern Portugal. A single specimen was collected in 1868, according to Heynemann (13), by Lucas Von Heyden, in the province of Asturias, in Northern Spain. Two other species, G. oliveira and G. anguiiformis, from Central and Southern Portugal, will be described in Simroth's forthcoming Memoir (40).†

Food.—G. maculosus undoubtedly lives on lichens, as I have been able to demonstrate by microscopic examination of the contents of the intestine.

In captivity it readily takes to other food, and thrives on dandelion leaves; and Heynemann (13) succeeded in keeping Irish specimens during a whole winter on lettuce, gherkins, &c.

General Distribution.†—Northern Portugal, and N. W. Spain.

*In May, 1891, I found this species abundantly still further South at Glengariff, county Cork.
† The question of the peculiar geographical distribution of this slug will be dealt with in a special Memoir, which I hope to publish during the course of this year.
The Colours of Slugs.

A good deal has been written in various Zoological works on the colours of animals in general, and Poulton has recently published a most interesting work, chiefly on the colours of Insects. He finds that a variety of causes influence the production of colours, but that by far their most widespread use is to assist an animal in escaping from enemies or in capturing its prey.

The view that colour is of direct physiological value to slugs has been ably argued by Simroth in the cases of *Arion ater* and *Limax maximus*, and Eimer (6) seems to support Leydig's view, that the darker colour of *A. ater* on the sea-coast may be caused by the greater moisture of the atmosphere. However, I hope I shall be able to show that neither of these views are altogether borne out by facts. Cockerell (4), judging from some specimens sent to him from a mountain in county Waterford, draws the conclusion that altitude influences the colour of slugs, but this also, I believe, is not supported by sufficient evidence.

I think that the colours of slugs in Ireland are at all ages, as a rule, protective. Simroth (38) agrees with this as far as the smaller species are concerned, but he excepts *Limax maximus* and *Arion empiricorum (= ater)*, because they are often distinguished by strikingly vivid colours.

He made numerous experiments with the latter species, kept it in a hot atmosphere, and offered it to various birds as food, and finally came to the conclusion that the colour in the brick-red variety is a warning colour. The object of a so-called warning colour, I may say, is to render the animal as conspicuous as possible, in order to enable its enemies to easily learn and remember the animals which are to be avoided on account of any noxious properties they may possess.

Simroth (38), moreover, points out that all the very variable species of slugs, such as *Arion ater* and *Limax maximus*, are darkly coloured both at their southern and northern limits of range, the shores of the Mediterranean, and Scandinavia. He supposes this to be due to a natural protection against heat and cold, *i.e.* he believes that colour is of direct physiological value.

We know, however, that dark colours absorb radiant heat easily, while light colours do so with difficulty; and it seems therefore surprising that Simroth (38) did not take into account the fact that the white variety of *A. ater* in Scandinavia is almost as common as the black [Esmark (7)]. Both on the Continent and in Ireland the young of *A. ater* are brilliantly coloured during winter, and most specimens darken at the approach of summer.

If Simroth's theory were correct, one would expect the slugs which are destined to resist the severe cold of a Continental winter to be coloured dark. All young specimens, however, whether they produce black or brown adults, are light-coloured
in their youth, and the colour of the adults varies between black, brown, and red in Germany, just as it does in Ireland, with the exception that the brick-red form so common in Germany is absent with us.

Simroth’s experiment of offering *A. ater* as food to various birds, and its being refused by them, does not seem to me conclusive, as birds kept in captivity get a regular diet, and become in time rather dainty feeders. Besides, large birds such as gulls, are decidedly rare in Germany, and I think it much more likely that toads or some of the insectivorous mammals do a great deal of damage among slugs; and it is possibly these that have a particular aversion to the bright red slugs, owing to their more acrid slime. Their colour is certainly most conspicuous, and on a rainy day they are often seen in hundreds in broad daylight in the forests of Germany.

I do not believe their colour is influenced by the temperature, for we find black and brown forms of the same species living in such a dry climate as that of Eastern Germany and on the very humid West Coast of Ireland—in cold and bleak Norway as well as on the parched plains of Spain and Portugal.

In this country, as I mentioned before, I have met with the uniformly black, the brown, olive, claret, and light red varieties of *A. ater*, and one variety which is black above, with yellow sides. The olive and light red forms occur only on the West Coast, but the black and brown ones are equally common there. In boggy ground most of those I saw were either olive or a rich burnt sienna brown. Their colour harmonizes most perfectly with the brown of the turf and the olive-coloured moss growing on it. I have also observed the light red in that neighbourhood, but no natural object seemed to me to exactly resemble it.

Perhaps the wettest spot on the West Coast is the Skellig Rock, an immense rock, entirely bare, over the greater part of which the huge Atlantic waves break, scattering their spray completely over the highest parts. From this rock I have the olive and black variety of *A. ater*. If moisture caused darkness, they would all be black there, for a more humid place can scarcely be imagined.

Certainly, I have everywhere met with black specimens very close to the sea, both on the West and especially on the East Coast, and that fact taken alone might lead us to suppose that moisture had something to do with the darkness of their colour; but black specimens are equally common inland a long way from the sea, whilst on cultivated ground, even if it should be quite close to the shore, we find almost invariably the brown variety.

Another remarkable circumstance is that along the sea-shore near Dublin one meets very frequently with the black and yellow variety, *i.e.* black with yellow sides (Plate LVI., fig. 15.) A variety with white sides has been recorded from the coast of Wales, and Simroth obtained them also from the shores of the German Ocean.
It seems clear that the sea has some connexion with this variety at any rate, but I think its connexion is only of an indirect nature. It struck me at first that the sides of the slugs might be more stimulated to secrete mucus than the back, as the animals would have to crawl over grass which must be coated with depositions of salt; but why should they not then all be of that variety near the sea? Entirely black ones are, in fact, rather more common.

There is another more likely explanation to account for the fact of the bicoloured dress of the young being retained in the adult on the sea-shore. It appeared to me that in the twilight of morning and evening the black-and-yellow forms might have equal advantages of concealment with the black ones, when crawling among the stones at the sea-shore, for I believe this species is just as much preyed upon as other slugs by the innumerable birds frequenting Dublin Bay. It is well known that the gizzard of gulls is frequently found to be filled with slugs of all kinds, whilst Thompson (43) often found the shell of Limax maximus and Agriolimax in the stomach of the thrush.

The only place where I have found the claret-coloured variety was in pine woods at Killakee and Howth, where the general colouring of the ground resembles that of the slug, and at once suggested to me the protective character of its colour. As regards the young winter forms of Arion ater, I have always noticed that they choose the yellow fallen leaves, whose colour they resemble very closely, for hiding-places, and here again it is the need of protection and not temperature which influences their colouring.

As for the other species of slugs, we have very good examples of protective colouring in Limax marginatus, Amalia carinata, Arion intermedius, and Geomalacus maculosus. The first, when on a tree-trunk, which is its favourite haunt, is easily mistaken for a piece of bark; the second resembles the ground in which it spends almost its entire existence; the third looks very like a little fungus just coming out of the ground, while the last imitates the colour of the lichen among which it lives to a remarkable degree.

In the other slugs protective colouring is perhaps not quite so apparent, but I have no doubt that in all cases their colour is mainly influenced by the natural selection of those best suited to escape the keen sight of their enemies.
PAPERS AND WORKS REFERRED TO.

25 Malm, A. W., "Skandinaviska Land Sniglar."—1870.
28 Müller, O. F., "Vermium terrest. et fluv. historia."—1774.
30 Normand, N. A. J., "Descr. de six Limaces nouvelles."—1852.
34 Reeve, L., "Land and Freshwater Mollusca of the British Isles."—1863.
35 Roebuck, W. D., Numerous Notes and Papers.—Journal of Conchology, vols. 4-6, 1888-1890.
36 Scharff, R. F., "Arion minimus (Simroth) a British Slug."—Journal of Conchology, vol. 6, 1890.
43 Thompson, W., "Natural History of Ireland," vol. 4, 1856.
EXPLANATION OF PLATE LVI.
EXPLANATION OF PLATE LVI.

Fig.
1. *Limax maximus*, L., dark variety (rather more than half-grown), from Raheny, Co. Dublin.
2. ,, ,, (not quite half-grown), from Leeson Park, Dublin.
3. ,, *flavus*, L. (full-grown), from Raheny, Co. Dublin.
4. ,, *marginatus*, Müller (full-grown), from Killakee, Co. Dublin.
6. ,, ,, L., variety (full-grown) from Rathfarnham, Co. Dublin.
7. ,, *laevis*, Müller (twice natural size, almost full-grown), from Killakee, Co. Dublin.
8. *Amalia carinata*, Leach (full-grown), from Leeson Park, Dublin.
11. ,, ,, variety (half-grown), resting position, from Raheny, Co. Dublin.
12. ,, ,, variety (half-grown), not fully extended, from Howth, Co. Dublin (Redding).
13. ,, ,, variety (young), from Killakee, Co. Dublin.
14. ,, ,, brown variety (young of fig. 10), from Leeson Park, Dublin.
15. ,, ,, variety (half-grown), from Howth, Co. Dublin (Redding).
16. ,, ,, variety (half-grown), from Rathfarnham, Co. Dublin.
17. ,, *subfuscus*, Drap. (full-grown), from Raheny, Co. Dublin.
18. ,, ,, variety (full-grown), from Howth, Co. Dublin.
19. ,, ,, variety (full-grown, sexually undeveloped), Killakee, Co. Dublin.
20. ,, *hortensis*, Fér., brown variety (1½ times natural size, full-grown), Leeson Park, Dublin.
21. ,, *bourguignatii*, Mabille, brown variety (1½ times natural size, full-grown), Leeson Park, Dublin.
22. ,, *intermedius*, Normand (full-grown), from Raheny, Co. Dublin.
23. ,, ,, ,, variety (full-grown), resting position, from Killakee, Co. Dublin.
EXPLANATION OF PLATE LVII.
LETTERING ADOPTED IN ALL THE FIGURES.

\begin{align*}
\text{hg.} & \quad \text{hermaphrodite gland.} \\
\text{hd.} & \quad \text{hermaphrodite duct.} \\
\text{sg.} & \quad \text{albuminiparous gland.} \\
\text{os.} & \quad \text{ovesperm-duct.} \\
\text{ov.} & \quad \text{oviduct.} \\
\text{sp.} & \quad \text{sperm-duct.} \\
\text{rec.} & \quad \text{receptaculum seminis.} \\
\text{p.} & \quad \text{penis.} \\
\text{rm.} & \quad \text{genital retractor muscle.} \\
\text{fl.} & \quad \text{flagellum.} \\
\text{pat.} & \quad \text{portion of sperm-duct in which spermatophore is formed (Patronenstrecke).} \\
\text{vs.} & \quad \text{upper vestibule.} \\
\text{lv.} & \quad \text{lower vestibule.} \\
\text{ac.} & \quad \text{accessory gland.} \\
\end{align*}

EXPLANATION OF PLATE LVII.

Fig.
25. \textit{Limax maximus}, L. (reproductive organs), very dark form, from Killakee, Co. Dublin, October, 1890.
26. ,, \textit{fuscus}, L. (reproductive organs), from Raheny, Co. Dublin, October, 1890.
27. ,, \textit{marginatus}, Müller (reproductive organs), from Co. Wexford, August, 1890.
28. \textit{Agriolimax agrestis}, L. (reproductive organs), magnified, from Aran Islands, October, 1890.
29. ,, \textit{laevis}, Müller (reproductive organs), magnified, from Killakee, Co. Dublin, September, 1890.
30. \textit{Amalia carinata}, Leach (reproductive organs), magnified, from Aran Islands, October, 1890.
31. ,, \textit{quadriculata}, Drap. (reproductive organs), from Raheny, Co. Dublin, September, 1890.
32. \textit{Arion ater}, L. (reproductive organs), black variety, from Raheny, Co. Dublin, August, 1890.
33. ,, \textit{subfuscus}, Drap. (reproductive organs), magnified, from Raheny, Co. Dublin, September, 1890.
34. ,, \textit{hortensis}, Férr. (reproductive organs), magnified, from Leeson Park, Dublin, October, 1890.
35. ,, \textit{bourguignati}, Mabille (reproductive organs), magnified, from Leeson Park, Dublin, July, 1890.
36. ,, \textit{intermedius}, Normand (reproductive organs), magnified, from Raheny, Co. Dublin, September, 1890.
37. \textit{Geomalacus maculosus}, Allman (reproductive organs), from Co. Kerry, May, 1890.
Plate LXII.

25. Limax maximus.

26. Limax flavus.

27. Limax marginalis

28. Agriolimax laevis

29. Agriolimax agrestis

30. Amalia gagates.

31. Amalia carinata

32. Arion ater

33. Arion atterÆ

34. Arion hortensis

35. Arion bourguignati

36. Arion intermedius

37. Geomalacus maculosus
TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1–25.—November, 1877, to September, 1883. (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1–2.—August, 1879, to April, 1882. (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1–14.—September, 1883, to November, 1887. (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.


3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.


5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.


7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleostaeans. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.


ON THE CAUSE OF DOUBLE LINES AND OF EQUIDISTANT SATELLITES IN THE SPECTRA OF GASES. By GEORGE JOHNSTONE STONEY, M.A., D.Sc., F.R.S., Vice-President, Royal Dublin Society.
ON THE CAUSE OF DOUBLE LINES AND OF EQUIDISTANT SATELLITES IN THE SPECTRA OF GASES. BY GEORGE JOHNSTONE STONEY, M.A., D.Sc., F.R.S., Vice-President, Royal Dublin Society.
XI.

ON THE CAUSE OF DOUBLE LINES AND OF EQUIDISTANT SATELLITES IN THE SPECTRA OF GASES. BY GEORGE JOHNSTONE STONEY, M.A., D.Sc., F.R.S., Vice-President, Royal Dublin Society.

[Read March 26 and May 22, 1891.]

CONTENTS.

<table>
<thead>
<tr>
<th>CHAP.</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.—Introduction,</td>
<td>563</td>
</tr>
<tr>
<td>II.—The problem treated dynamically.</td>
<td>569</td>
</tr>
<tr>
<td>III.—The problem treated from the standpoint of the Electro-magnetic Theory of Light.</td>
<td>582</td>
</tr>
<tr>
<td>IV.—Analysis by Fourier's Theorem,</td>
<td>585</td>
</tr>
<tr>
<td>V.—Illustrations,</td>
<td>592</td>
</tr>
<tr>
<td>VI.—Applications,</td>
<td>594</td>
</tr>
<tr>
<td>Postscript,</td>
<td>607</td>
</tr>
</tbody>
</table>

CHAPTER I.

INTRODUCTION.

The study of the kinetic theory of gases has been pursued during the last forty years with great success, by Clausius, Clerk Maxwell, and others, and has thrown a flood of light upon the conditions under which the molecules of ponderable matter subsist in the world about us. By these investigations it was discovered that, while in solids and liquids they are so crowded together as to be unremittingly under the influence of one another, a very different state of things prevails in gases. In gases the moments of time during which the molecules are close enough to act on one another are brief compared with much longer intervals which elapse between their encounters. During these comparatively long periods of independence each molecule is free to move in its own natural way; and important physical events on a large scale take place as a consequence of the motions within the molecules which then occur.

Previously to these inquiries, Dulong and Petit had obtained by experiment the law that the specific heat at constant volume of the more perfect gases is inversely proportional to their specific gravity. It is further known by experiment that $\gamma$,
the ratio of the specific heat at constant pressure to the specific heat at constant volume, is nearly the same for all these gases, and that its value is 1.408.

From these data the kinetic theory of gases enables us to gain our first insight as to what is going on within the molecules. These experiments, when interpreted by its help, show that only 0.012 of the energy in the more perfect gases is accounted for by the motions of the molecules as they dart about amongst one another like missiles, and that the remaining 0.388 of the whole energy is the energy of events that are going on within the molecules themselves.

We learn from electrical, thermal, and spectroscopic observations that energy can pass from the molecules of a gas to the æther; and we know that when a gas warms its containing vessel or expands against pressure, external work is done by it upon ponderable matter. Now it is very important to observe at the threshold of our inquiry that these are the only ways in which any energy whatever is expended by a gas. Retarding forces of one kind or other arise in all the motions with which we are most familiar on the earth, because the motions we are accustomed to take notice of are molar motions of the irrotational type, pursued under such conditions that part of the molar energy is constantly leaking down into subsidiary molecular activities. When, however, we get to the bottom of the series of irrotational motions, beneath which there are none underlying, no such degradation of energy is possible. Accordingly there is absolutely no loss of energy in the encounters between molecules; neither is there a trace of anything like friction or viscosity between the different parts of a molecule to impede any events that may be going on within it during its flight between one encounter and the next. All its internal motions are even more free from any such interference than are the motions of the planets, which are affected, in a minute degree, both by meteors and by tidal actions.

Very striking information about these internal events is furnished by the spectroscope, which reveals to us the fact that they are such as to occasion definite undulatory changes in the surrounding æther. Each gas is in fact found to emit an interrupted spectrum, consisting of separated lines; of which the positions, intensities, and general appearance are characteristic of the molecules from which they emanate. We thus become aware of the fact that each gaseous molecule, and as a consequence each chemical atom, is an elaborate system within which highly complex changes of a periodic character are perpetually taking place.

The object of the present communication is to try to cross the threshold of an inquiry as to what these molecular events are.

In this investigation we shall have to treat of periods of time too small to be conveniently spoken of as fractions of a second. And, fortunately, the nature of the subject indicates the best way of dealing with them. This is by making use of the velocity of light and other electro-magnetic waves in the open æther, which
is one of the three fundamental fixed units of nature.* This standard velocity I propose to call the Maxwell. It is a velocity of almost exactly 30 quadrants of the earth per second, meaning by a quadrant the distance along the earth’s meridian from the equator to the pole—in other words, it is a velocity of 300 millions of metres per second. It is a velocity that pervades all nature and establishes a natural relation, which exists everywhere, between time and length. Accordingly lengths, such as metres, millimetres, &c., do naturally represent definite periods of time, viz. the times occupied by light in advancing over those distances in the open æther. But as perhaps it might be thought too great a departure from usage to speak of metres, millimetres or tenth-metres† of time, I shall for our present purpose select one definite period, viz. the time that light takes to advance the tenth part of a millimetre, and will call it the jot of time. This little fragment of time, which is one-third of the billionth of a second, will be found a very convenient standard in which to measure the periods which present themselves in the study of molecular events. Thus light takes one deka-jot to advance a millimetre; it advances a tenth-metre in the micro-jot, meaning by the deka-jot, ten jots, and by the micro-jot, the millionth part of a jot. The periodic times of the oscillations that present themselves in the spectra of gases range from a little less than two milli-jots up to about twelve milli-jots, meaning by the milli-jot the thousandth part of a jot. This range extends from the limit in the ultra-violet explored by Professor Hartley to the farthest ultra-red reached by Captain Abney. In ordinary air the flight of a molecule between its encounters lasts on the average about 420 jots,‡ during which time there can, accordingly, take place upwards of 200,000 of the swiftest and 30,000 of the slowest of the oscillations§ spoken of above—oscillations which we must bear in mind are set up in the surrounding æther by the events that occur in the molecules.

† A tenthmet means a unit in the tenth place of decimals; in other words it is \(1/10^{10}\).
‡ The rate of diffusion of gases and the amount of their viscosity depend on the length of the excursion of the molecules. Maxwell made three determinations founded on this consideration, the mean of which is that the average length of the free path in air is a little more than seven eighth-metres (\(7/10^8\) of a metre). See Phil. Mag. for August, 1868, p. 138, where Maxwell’s results are collected. Taking seven eighth-metres as the length of the excursion, and 500 metres per second (the “velocity of mean squares” in air at 18° temperature) as the speed of the molecule, the mean duration of its flights will be 420 jots. It is probably a little more than this in air, and will vary in different gases and in the same gas under different circumstances; but for the purposes of this Paper a very rough approximation is sufficient, and accordingly we shall use 420 jots when we want to indicate the sort of interval of time that elapses while a molecule is on one of its journeys.
§ The word oscillation is used throughout this Paper in a generalized sense to include revolutions in an orbit as well as vibrations in a straight line.
The first step to connect these æthereal oscillations with motions in the molecules was I believe taken by the author when, in 1870, he pointed out the harmonic relation which exists between the lines $a$, $\beta$, and $\delta$ of the line spectrum of hydrogen. These are the lines $C$, $F$, and $h$ of the solar spectrum. Their periodic times are inversely as the numbers $20:27:32$. This gives evidence that these three lines have their source in some one event in the molecules of hydrogen. The next step was taken by Professor J. Emerson Reynolds and the author working in conjunction in the laboratory of the Royal Dublin Society in 1871, when, on a careful examination of the spectrum of chlorochromic anhydride ($\text{CrO}_2\text{Cl}_2$), it was ascertained that the sequence and intensities of a very long series of lines in the absorption spectrum of that ruddy vapour, stand in a close relationship to the sequence and intensities of the series of harmonics emitted by a violin under definite circumstances, viz. when the string is bowed at a point nearly, but not quite, two-fifths of its length from the bridge.* From this, and from the regularity in the spacing of the lines, it appears that all the lines of this long series have their source in some one event occurring in the molecules of the vapour. It was also ascertained by mixing air with the vapour that this event is one which is independent of the encounters that must then occur between molecules of the vapour and molecules of the air. It is therefore probably a periodic event excited and maintained by the incident light during the comparatively long periods of flight of the molecules, which, in the experiments that were made, lasted over some hundreds of jots, and not during the very much briefer periods when the molecules are now and then grappling with one another in struggles, no one of which probably can last more than some very few jots. During these brief encounters we must presume that the motions excited by the incident light are, on the contrary, in part obliterated, since some of the energy which is absorbed from the æther increases the pressure of the vapour.

The next notable event was the discovery by Dr. Huggins, that the four hydrogen lines of the solar spectrum are part of a much longer series of lines arranged in a conspicuous pattern, which is evidence that they are due to some common cause. Dr. Huggins found the additional lines in the spectra of white stars. They are absent from our Sun. This discovery was shortly followed by a laboratory investigation, confirming the opinion suggested by the telescopic observation, viz. that the whole series is due to hydrogen.

Then followed the very important discovery of "Balmer's Law." Professor Balmer, in 1885, showed that the law connecting three of the hydrogen lines, to which the author had called attention in 1870, is part of a more comprehensive law which includes the whole series. This comprehensive law is that

* See Phil. Mag. for July, 1871, p. 47.
The oscillation-frequencies of the successive lines is given by the formula
\[ n_{m-2} = k \left( 1 - \frac{4}{m^2} \right), \]
in which \( k \) is a constant for the whole series. By putting, successively, into this formula the whole numbers 3, 4, 5, 6, &c., for \( m \), it furnishes values for \( n \), which are the oscillation-frequencies of the successive lines. This still further establishes the fact that these rays are caused by one event, or by one body of inter-dependent events, occurring in the molecules of the gas. It can easily be seen that the 1st, 2nd, and 4th of this series are \( \frac{3}{2}, \frac{5}{2}, \) and \( \frac{7}{2} \), in accordance with the law which I had announced in 1870.

There are many series of lines known to spectroscopists which form patterns somewhat like that of the hydrogen series, and which we may presume are to be referred to some one event or group of associated events occurring in the molecules of the gas. The discovery of Balmer’s law has stimulated other inquirers to search for similar simple laws connecting the oscillation-frequencies in cases of this kind; and these attempts have at all events elicited useful approximate laws, which have done science the service of making it possible for the investigator in many important cases to pick out the members of an associated series of lines, where the individual lines are too far separated, or too much mixed up with lines not belonging to the series, for his eye to detect the association upon mere inspection.* Most useful work of this kind has been carried on by Professors Kayser and Runge in Germany and by Professor Rydberg in Sweden. It must suffice here to give an outline of those results of Professor Rydberg’s analysis of the spectra of the monads lithium, sodium, potassium, ruthenium, and caesium, to which a new and special meaning is imparted by the investigation in the present Memoir.

Both Professor Rydberg and Professors Kayser and Runge find† that the spectrum of each of these elements contains and almost altogether consists of three series of double lines. The distribution of the pairs constituting each series over the spectrum is such as to form a pattern somewhat like that of the great hydrogen series to which Balmer’s law applies, although no equally simple law has been detected connecting their positions. We shall presently see

* The first work of this kind with which I am acquainted was the successful separation of one of the bands of the spectrum of CO into two distinct series by Professor Alexander Herschel in 1883. See Transactions R. S. Edinb., vol. xxxii., p. 454. It was carried out before the announcement of Balmer’s law, by the help of a harmonic law.

that the oscillations of the lines in these spectra are not quite synchronous with the motions in the molecules that originate them, while in hydrogen, by reason of the extreme closeness of the double lines, they are almost exactly synchronous. It will also be shown how the periodic times of the molecular motions may be deduced from the observations.

Professor Rydberg designates by the letters $P$, $D$, and $S$, the three series of pairs of lines found in the spectrum of each of the foregoing elements: $P$ being what he calls the *principal* series of pairs of lines, $D$ a series of pairs of *diffuse* or nebulous lines, and $S$ a series of pairs of *sharp* lines. All the observations he has been able to collect support the conclusion that the more refrangible line of each pair of the series $P$ is the stronger, while the reverse is the case in the two other series. What this means will appear in the sequel.

Professor Rydberg is of opinion that when the lines are plotted down on a map of oscillation-frequencies, the distance between the two lines of each pair, which we may call $\Delta$, is the same throughout the whole of each series, and even in all the three series. It may be doubted whether the observations he has collected are as yet sufficient to give us confidence on this point. It will doubtless be settled by the great photographs that Professor Rowland has succeeded in obtaining with his unrivalled apparatus, and which we may hope will soon be published. It may, however, prove to be the case; and we shall see in the following chapters the important meaning which would attach to it.

Finally, Professor Rydberg has ascertained that the value of $\Delta$ (the interval between the lines of each pair), while it varies but little between the three series of pairs of lines in each element, differs very much in passing from one element to another: the pairs being closest in lithium, somewhat wider in sodium, wider still in potassium, very wide in rubidium, and widest of all in caesium. What this means will also be explained.
CHAPTER II.

THE PROBLEM TREATED DYNAMICALLY.

The alternations of electro-magnetic stress in the æther which constitute light form an undulation which is propagated under the same laws as the transverse vibrations of a suitable medium. We shall in the present chapter treat the subject under this purely dynamical hypothesis, and will in the following chapter make those corrections which are required to convert the investigation into one under the electro-magnetic theory of heat and light.

We shall accordingly, for the present, regard certain points in the molecules of the gas as acting dynamically on an æther capable of receiving and transmitting only transverse vibrations, and we have to inquire what motions of these points within the molecules would impart to the medium the oscillations which correspond to the observed lines in the spectrum.

Let us then fix our attention on a particular molecule $M$, and suppose that a point $P$ in it which acts on the æther has been set moving along some orbit within the molecule by the last of the inter-molecular encounters to which $M$ has been subjected. We are in ignorance as to what the forces are, under the influence of which the point $P$ will continue its motion during the flight of the molecule; but, nevertheless, there is one case which admits of treatment up to a certain point; and on comparing the conclusions of this treatment with the simplest spectra—those of the light monad elements—we find that the conditions which lead to it occur in them. We shall confine our attention in the present Memoir to this case. It presents itself whenever one or some forces acting on $P$ are predominant over all the others, and the treatment to be employed is the same as that with which we are familiar in the lunar and planetary theories. In applying this method the real course of the point $P$ is to be arrived at by first laying down its "dominant orbit," that is the path which $P$ would pursue if the dominant forces were the only ones acting on it, and by then subjecting this orbit to perturbations while $P$ is traversing it. These perturbations are of two kinds:—$(1^\circ)$ such a gradual shifting of the position of the dominant orbit while $P$ is revolving round it, as will bring $P$ at each instant to the real position which it actually does then occupy under the influence of all the forces; accompanied by $(2^\circ)$ such a gradual change of the form of the dominant orbit as may be necessary to render it at each instant the orbit which $P$ would describe if the perturbing forces were then suddenly to cease acting. If the perturbing forces be feeble these changes will be slow as well as
gradual, slow in comparison with the much more rapid motion of $P$ in the dominant orbit, which is going on at the same time.

However complex the dominant orbit may be, it will be shown in Chapter IV. that the motion of $P$ in it is equivalent to the coexistence and superposition of a number of "partials," each of which is a pendulous elliptic motion of $P$ represented by—

$$
x = a \cos \theta t, \\
y = b \sin \theta t, \\
$$

(1)

$a$, $b$ and $\theta$ being constants which differ in the different partials. $\theta$, which is the angular velocity of the growing angle $\theta t$, may also be called the \textit{swiftness} of the elliptic motion. It is the same as $2\pi m/j$, where $m$ is the \textit{frequency} of the elliptic revolutions in a jot of time. The \textit{periodic time} is, of course, $j/m$. The value of $m$ must lie between 80 and 500, whenever the frequency of this elliptic motion is the same as that of any undulation in the ether which can produce a line in the parts of the spectrum that have been explored; and as in ordinary air each molecular journey lasts on the average about 420 jots, there is time for a vast number—say from 35,000 to 210,000—of the revolutions of the point $P$ represented by equations (1) to take place during one flight of the molecule.

If the dominant orbit of $P$ were the real orbit of $P$, each of its partials would produce a single line in the spectrum. But it is not likely that the motion can go on without its being affected by disturbing forces emanating from other parts of the molecule, or from the ether in its neighbourhood; and so many revolutions of $P$ take place during one of the flights of the molecule that there is abundant time for the operation of these disturbing forces. Now, the investigations that have been made into the perturbations which occur within the solar system enable us to predict at once what kinds of effects such disturbing forces would produce. They are (1°) an apsidal motion of the elliptic partial in its own plane; (2°) a precessional shifting of the line of nodes in which this plane intersects the "invariable plane"; (3°) a periodic change in the inclination of these two planes; (4°) a periodic change of the ellipticity of the partial. All these may be regarded as perturbations of relatively long period, but the conditions within the molecule may be such as to occasion (5°) disturbances of shorter period affecting any one or more of the foregoing, and producing an effect on them somewhat like that of nutation superimposed upon precession. We shall accordingly proceed to inquire how each of the foregoing perturbations would manifest itself in the spectrum.

The first problem of this inquiry only requires to be enunciated. It is—

\textbf{Problem I.}—How will a simple elliptic motion of $P$ in the molecules of the gas, such as that represented by equations (1), manifest itself in the spectrum of the gas?
It will obviously give rise to a single line in the spectrum, whose position on a map of oscillation-frequencies is \( m \), and whose intensity may be represented by \( a^2 + b^2 \).

**Problem II.**—How will this simple spectrum be altered if there is an apsidal motion of the ellipse in its own plane?

Draw rectangular axes of co-ordinates from the centre of the ellipse as origin, and at an angle \( \psi t \) with the axes \( Ox \) and \( Oy \) of equation (1). Regard the axes \( OX \) and \( OY \) as fixed, and let \( \psi = 2\pi n/j \). The ellipse will then travel round with an apsidal motion such that \( n \) is the frequency of the apsidal circuits in one jot of time. The co-ordinates of \( P \) referred to the fixed axes are:

\[
\begin{align*}
X &= a \cos \theta t \cos \psi t - b \sin \theta t \sin \psi t; \\
Y &= a \cos \theta t \sin \psi t + b \sin \theta t \cos \psi t.
\end{align*}
\]

equations which are equivalent to

\[
\begin{align*}
X &= \frac{a + b}{2} \cos (\theta + \psi)t + \frac{a - b}{2} \cos (\theta - \psi)t; \\
Y &= \frac{a + b}{2} \sin (\theta + \psi)t - \frac{a - b}{2} \sin (\theta - \psi)t.
\end{align*}
\]

In other words,

\[
\begin{align*}
X &= X_1 + X_2, \\
Y &= Y_1 + Y_2,
\end{align*}
\]

where

\[
\begin{align*}
X_1 &= + \frac{a + b}{2} \cos (\theta + \psi)t, \\
Y_1 &= + \frac{a + b}{2} \sin (\theta + \psi)t.
\end{align*}
\] (3a)

and

\[
\begin{align*}
X_2 &= + \frac{a - b}{2} \cos (\theta - \psi)t, \\
Y_2 &= - \frac{a - b}{2} \sin (\theta - \psi)t.
\end{align*}
\] (3b)

each of which represents a circular motion. Accordingly an elliptic motion whose frequency is \( m \), when affected by an apsidal perturbation whose frequency is \( n \), is equivalent to the motion of \( P \) resulting from the two circular motions represented by equations (3a) and (3b). These circular motions are in opposite directions,
their frequencies are \( m + n \) and \( m - n \), and their radii are \( (a + b)/2 \) and \( (a - b)/2 \).

If the molecules of the gas be immersed in an æther such as we have assumed, viz. one susceptible of transverse vibrations only, the foregoing motion will produce two lines in the spectrum whose positions on a map of oscillation-frequencies will be \( m + n \) and \( m - n \). Moreover, the ratio of the intensities of the two rays propagated in any one direction from the gas through the æther will be the ratio of \( (a + b)^2 \) to \( (a - b)^2 \), whether we take into account the contribution from one molecule only, or the combined effect of all the molecules.

We thus find that the double lines which are a conspicuous feature of all gaseous spectra, and of which the spectra of the monad elements appear wholly to consist, are accounted for by supposing that an apsidal perturbation operating during the journeys of the molecules between their encounters, affects the dominant motion set up in them by the encounters.

The equations hitherto given represent the motion when the apsidal motion is in the same direction as the elliptic, and here the more refrangible line, whose oscillation frequency is \( m + n \), is the brighter. If, however, the perturbing forces are such that the apsidal motion takes place in the opposite direction to the revolution of \( P \) in its ellipse, we must change the sign of \( \psi \) in all the equations; from which it appears that it is now the less refrangible line which is the brighter. If any of the elliptic partials should chance to be a circle, \( b = a \), and one constituent of the double line is of cypher intensity. Accordingly, the other alone will present itself in the spectrum, and will have in it the position \( m + n \) when the circular motion and the apsidal are in the same direction, and the position \( m - n \) when they are in opposite directions. And, finally, whenever the partial of the dominant motion represented by equations (1) is a mere vibration in a straight line instead of a revolution in an ellipse, \( b \), the axis minor, vanishes, and the intensities of the spectral lines (which are always to one another in the ratio of \( (a + b)^2 \) to \( (a - b)^2 \)) become equal.

The following figures represent the several cases which have been considered. All of them are met with in the actual spectra of gases.

Fig. 2 (a).—Spectrum of one of the partials of the dominant motion of \( P \), viz. of a pendulous elliptic revolution of \( P \) in the molecules of the gas such as that represented by equations (1).

Fig. 2 (b).—The double line into which this resolves itself when the elliptic motion in the molecules is affected by an apsidal motion in the same direction as the elliptic motion. In this case the more refrangible line is the stronger. See equations (3 a) and (3 b).
Fig. 3 (a).—Simple elliptic motion as before.

Fig. 3 (b).—The double line when the apsidal motion is in the opposite direction to the elliptic motion. Here the less refrangible line is the stronger. This case is represented by changing the sign of $\psi$ in equations (3 a) and (3 b).

Fig. 4 (a).—Spectrum of a simple circular partial. This case is represented by making $b = a$.

Fig. 4 (b).—Position to which this line is shifted when there is apsidal motion in the same direction.

Fig. 5 (a).—Spectrum of a circular partial as before.

Fig. 5 (b).—Position to which the line is shifted when there is apsidal motion in the opposite direction.

Fig. 6 (a).—Spectrum of a pendulous vibration in a straight line. This case is represented by making $b = 0$ in equations (1).

Fig. 6 (b).—The spectrum of this vibration subjected to apsidal motion. Here the constituents of the double line are equally strong. This case is represented by putting $b = 0$ in equations (3 a) and (3 b).

**Precessional Motion.**—Both the revolution of $P$ in the elliptic partial and the apsidal rotation of the ellipse, if not subjected to further disturbance, take place in a fixed plane; but unless special conditions are fulfilled within the molecules the perturbations will be such that this plane will shift its position in relation to the "invariable plane." To represent this motion let us conceive an axis perpendicular to the invariable plane and passing through the centre of the ellipse. This axis is called the invariable line. It will in general be oblique to the plane of the ellipse, and we are to suppose the plane of the ellipse to rotate round it while maintaining its inclination to it unchanged. Hence arises—

**Problem III.**—What change of the spectrum will result from a precessional rotation round the invariable line, of the plane in which the elliptic and apsidal motions take place?

Let us speak of the moving plane (the plane in which the elliptic and apsidal motions take place) as plane $B$; and let the invariable plane be called plane $A$. 4 M 2
The invariable line is a fixed line perpendicular to plane $A$, round which plane $B$ is to be regarded as rotating with a swiftness $\omega = 2\pi k/j$, in which $k$ is the frequency of this motion.

The apsidal motion has already resolved the original elliptic motion into two circular motions in plane $B$, viz.,

\[
\begin{align*}
X_1 &= + s \cos St, \\
Y_1 &= + s \sin St,
\end{align*}
\]

and

\[
\begin{align*}
X_2 &= + d \cos Dt, \\
Y_2 &= - d \sin Dt,
\end{align*}
\]

which are the same as equations (3 a) and (3 b) when for brevity we write $s$ and $d$ for $(a + b)/2$ and $(a - b)/2$, and $S$ and $D$ for $\theta + \psi$, and $\theta - \psi$.

Draw three fixed axes: $Oz$ along the invariable line, $Ox$ along the direction at which the intersection of planes $A$ and $B$ arrives at the instant $t$, and $Oy$ perpendicular to $Ox$ in plane $A$. Then if $a$ be the angle between the planes $A$ and $B$, equations (4 a) furnish

\[
x = s \cos St
\]

along the intersection of planes $A$ and $B$ at the instant $t$,

\[
y = s \sin St \cos a
\]

along a line in plane $A$ which is perpendicular to the intersection of $A$ and $B$ at the instant $t$, and

\[
z = s \sin St \sin a
\]

along the invariable line.

Equations (5 a) and (5 b) are an elliptic motion of $P$ in plane $A$, and when affected by the precessional motion $\omega t$ (where $\omega = 2\pi k/j$), furnish the circular motions

\[
\begin{align*}
\overline{X}_1 &= + s \cos^2 \frac{a}{2} \cdot \cos (S + \omega) t, \\
\overline{Y}_1 &= + s \cos^2 \frac{a}{2} \cdot \sin (S + \omega) t,
\end{align*}
\]

and

\[
\begin{align*}
\overline{X}_2 &= + s \sin^2 \frac{a}{2} \cdot \cos (S - \omega) t, \\
\overline{Y}_2 &= - s \sin^2 \frac{a}{2} \cdot \sin (S - \omega) t,
\end{align*}
\]

equations (5 c), (6 a), and (6 b) represent the whole effect; (5 c) is a rectilinear vibration of $P$ perpendicular to the invariable plane, and (6 a) and (6 b) are two
circular motions of $P$ in that plane. These will give rise to three lines in the spectrum, of which the positions on a map of oscillation-frequencies will be

$$m + n - k, \text{ position of } (6a)$$

$$m + n + k, \text{ . . . . (6b)}$$

and

$$m + n, \text{ . . . . (5c)}$$

with intensities proportional to

$$2s^2 \cos^4 \frac{\alpha}{2}, \text{ intensity of (6a)}$$

$$2s^2 \sin^4 \frac{\alpha}{2}, \text{ . . . . (6b)}$$

$$4s^2 \sin^2 \frac{\alpha}{2} \cos^2 \frac{\alpha}{2}, \text{ (5c)}$$

If $a$ is small, i.e. if the plane of the elliptic motion is nearly coincident with the invariable plane, as it probably is in the molecules of the monad elements H, Li, Na, Rb, Cs. then the line (6a) is strong, (5c) is faint, and (6b) is excessively faint.

The foregoing investigation traces what becomes of the circular motion (4a) when affected by precession. A similar treatment of (4b) is made by substituting $d$ for $s$ and $-D$ for $S$. We thus obtain the following:

$$X_1 = +d \cos^2 \frac{\alpha}{2} \cos (D - \omega)t$$

$$Y_1 = -d \cos^2 \frac{\alpha}{2} \sin (D - \omega)t$$

$$X_2 = +d \sin^2 \frac{\alpha}{2} \cos (D + \omega)t$$

$$Y_2 = +d \sin^2 \frac{\alpha}{2} \sin (D + \omega)t$$

and

$$z = -2d \sin \frac{\alpha}{2} \cos \frac{\alpha}{2} \sin Dt,$$

producing three lines in the spectrum in the positions

$$m - n - k, \text{ position of (9a)}$$

$$m - n + k, \text{ . . . . (9b)}$$

$$m - n, \text{ . . . . (10)}$$
with the intensities

\[
\begin{align*}
2d^2 \cos^4 \frac{a}{2}, & \text{ intensity of } (9a) \\
2d^2 \sin^4 \frac{a}{2}, & \ldots \ldots \ldots (9b) \\
4d^2 \sin^3 \frac{a}{2} \cos^3 \frac{a}{2}, & \ldots \ldots (10)
\end{align*}
\]

of which (when \(a\) is small) the first is strong, the third faint, and the second excessively faint.

Hence when one of the elliptic partials of the dominant motion of \(P\) is affected by both apsidal motion and precession, we shall have an appearance in the spectrum which may be represented diagrammatically by the following figures: where \((a)\) in each figure represents the spectrum of the original elliptic partial if undisturbed, \((b)\) what it becomes when there is apsidal motion, and \((c)\) what it becomes when there are both apsidal motion and precession.

All the figures are drawn to represent the state of affairs which is probably what prevails in the monad elements, viz. apsidal and precessional motions, which are slow in comparison with the revolution of \(P\) in the elliptic partials of its dominant motion. In this case \(n\) and \(k\) are small in comparison with \(m\). The three motions may be in the same direction, or one of them in the opposite direction to the other two. Hence arise four varieties.

**Variety 1.**—The elliptic, apsidal, and precessional motions in the same direction. Here \(m, n,\) and \(k\) are all positive, and the resulting spectrum may be represented diagrammatically by fig. 7 \((c)\), and consists of a pair of lines with satellites inside, the more refrangible group being the brighter.

**Variety 2.**—The precessional motion in the opposite direction to the other two: \(m\) and \(n\) are positive, and \(k\) negative.

![Fig. 7.](image-url)

![Fig. 8.](image-url)

Fig. 8 \((c)\) represents the spectrum: a pair, of which the more refrangible is the brighter, with satellites outside.
Variety 3.—The apsidal motion opposite the other two. Therefore $m$ is positive, $n$ negative, and $k$ positive.

Fig 9 (c) represents the spectrum: a pair, with satellites outside, the less refrangible group the brighter.

Variety 4.—The fourth variety is when both the apsidal and precessional motions are in the opposite direction to the elliptic. Here $m$ is positive, and $n$ and $k$ are negative, and the spectrum is represented by fig. 10 (c): a pair, with satellites inside, the less refrangible group the brighter.

![Fig. 9.](image)

![Fig. 10.](image)

These diagrams represent what occurs when the apsidal and precessional perturbations are slow compared with the original orbital motion aroused by the last encounter of the molecule with another molecule. In this case the satellites lie, as in the diagrams, on opposite sides of their primaries, and the primaries themselves have been displaced in opposite directions by the precessional motion.

If, however, the apsidal motion be swift, the orbital motion must be slow to account for the close double lines that are seen in the spectrum. Such relative swiftness of the apsidal motion seems unlikely, and accordingly I will not pursue the supposition further than to remark that if it prevails in any gas the satellites of both components of a double line will lie on the same side of their primaries, i.e. either all to the right or all to the left; and the primaries themselves will be displaced in the same, instead of in the opposite directions, by precession.

Corollary.—If there be precessional motion of an elliptic partial without apsidal motion, there will be three equidistant lines in its spectrum, of which the intensities could be computed if $a$, $b$, $a$ and $\beta$ were known, $\beta$ being the angle between the axis major of the ellipse, and the line in which the plane of the ellipse intersects the invariable plane. For the converse problem, we can observe the intensities of the three lines, and their interval. These will determine the value of $k$, and will furnish three equations between $a$, $b$, $a$ and $\beta$, but will not fully
determine these latter. The middle line has the position which would be occupied if there were no precessional motion.

The next matter to be considered is the effect of a periodic change in the inclination of the two planes. Hence—

Problem IV.—In what way will the spectrum of the gas be affected if there be a periodic change in the inclination of the plane of the ellipse to the invariable plane?

This problem is to be investigated exactly in the same way as Problem VI., which is dealt with a few pages farther on. Since the angle \( a \) in equations (5\( e \)), (6\( a \)), and (6\( b \)) undergoes a periodic fluctuation, we are to write \( (y + h \sin \eta t) \) instead of \( a \) in those equations, \( y, h, \) and \( \eta \) being constants. If after making this substitution we apply to the equations the same method of treatment as in Problem VI., we shall find that the effect of the perturbation is to render the lines winged.

Problem V.—What effect on the spectrum will a periodic change of ellipticity have?

The change of ellipticity may take place in either of two ways: in one the orbit will pass through a rectilinear form; in the other it will pass through a circular form.

I.—To represent a change of the first kind we must substitute for \( a \) and \( b \) of equations (1) the following:

\[
(r \cos \epsilon t) \text{ for } a,
\]
\[
(r \sin \epsilon t) \text{ for } b,
\]

where \( \epsilon = 2\pi \eta /j \), \( \epsilon \) being the frequency of the periodic change of ellipticity. We thus get instead of equations (1)

\[
x = r \cdot \cos \epsilon t \cdot \cos \theta t,
\]
\[
y = r \cdot \sin \epsilon t \cdot \sin \theta t,
\]

which treated as in Problem II. give

\[
x = \frac{r}{2} \left[ \cos (\theta - \epsilon) t + \cos (\theta + \epsilon) t \right],
\]
\[
y = \frac{r}{2} \left[ \cos (\theta - \epsilon) t - \cos (\theta + \epsilon) t \right].
\]

These equations represent two rectilinear motions at right angles to one another, of frequencies \( m + \epsilon \) and \( m - \epsilon \), and of equal intensity. They, accordingly, would give rise to a pair of equal lines in the spectrum of the gas. If there be absidal motion also, each of these will be doubled, and two pairs of equal lines will present themselves.
II.—To represent a periodic change of ellipticity, in which the orbit passes through a circular form, we must substitute in equations (1)

\[ (r + \rho \cos \epsilon t) \text{ for } a, \]
\[ (r - \rho \cos \epsilon t) \text{ for } b, \]
where \( \epsilon = 2\pi e/\tau \). We thus obtain

\[ x = (r + \rho \cos \epsilon t) \cos \theta t, \]
\[ y = (r - \rho \cos \epsilon t) \sin \theta t, \]
which are equivalent to

\[ x = r \cos \theta t + \frac{\rho}{2} \cos (\theta + \epsilon) t + \frac{\rho}{2} \cos (\theta - \epsilon) t, \]
\[ y = r \sin \theta t - \frac{\rho}{2} \sin (\theta + \epsilon) t - \frac{\rho}{2} \sin (\theta - \epsilon) t. \]

This motion, if \( \rho \) is small, produces a line at frequency \( m \), with two equal satellites at frequencies \( m + e \) and \( m - e \), i.e. one on either side of the primary.

Another perturbation which may possibly present itself would consist in the alternate contraction and dilatation of the ellipse. This is represented by the equations

\[
\begin{align*}
  x &= a \cdot \cos \epsilon t \cdot \cos \theta t, \\
  y &= b \cdot \cos \epsilon t \cdot \sin \theta t,
\end{align*}
\]

where \( \theta = 2\pi m/j \) and \( \epsilon = 2\pi e/j \). The energy of this motion is \((a' + b')/2\), if we represent the energy of the simple elliptic motion of equations (1) by \( a^2 + b^2 \).

Problem VI.—What appearance in the spectrum would this perturbation occasion: 1°, if alone; 2°, if accompanied by an apsidal shifting of the ellipse?

1°. Equations (13 a) are equivalent to

\[
\begin{align*}
  x &= \frac{a}{2} \cos (\theta + \epsilon) t + \frac{a}{2} \cos (\theta - \epsilon) t, \\
  y &= \frac{b}{2} \sin (\theta + \epsilon) t + \frac{b}{2} \sin (\theta - \epsilon) t.
\end{align*}
\]

Hence the perturbation, when alone, occasions two equal lines of intensity \((a^2 + b^2)/4\), at the positions \( m + e \) and \( m - e \) on a map of oscillation-frequencies.

2°. Equations (13 b) are equivalent to

\[
\begin{align*}
  x &= x_1 + x_2, \\
  y &= y_1 + y_2,
\end{align*}
\]

where

\[
\begin{align*}
  x_1 &= \frac{a}{2} \cos St, \\
  y_1 &= \frac{b}{2} \sin St, \\
  x_2 &= \frac{a}{2} \cos Dt, \\
  y_2 &= \frac{b}{2} \sin Dt.
\end{align*}
\]
Let the system which is equivalent to the coexistence of motion in these two orbits undergo an apsidal shift, the frequency of which is \( n \). Then, proceeding as in Prop. II., we find that each of the two orbits gives rise to a double line. We thus get four lines at the positions and with the intensities.

\[
\begin{array}{|c|c|}
\hline
\text{Positions} & \text{Intensities} \\
\hline
m + e + n & (a + b)^2/8 \text{ equal.} \\
m - e + n & (a + b)^2/8 \\
m + e - n & (a - b)^2/8 \text{ equal.} \\
m - e - n & (a - b)^2/8 \\
\hline
\end{array}
\]

Hence when the perturbation is accompanied by apsidal motion there will be four lines, which will appear in the spectrum, as in \((a)\) or \((b)\) of fig. 11, if \( e \) is greater than \( n \); and as in \((a)\) or \((b)\) of fig. 12, if \( e \) is less than \( n \).

It remains to consider what appearance in the spectrum would present itself if there be a periodic oscillation in any of these perturbations, such as nutation produces on the precessional motion of the earth. Let us—to take one instance—suppose that the apsidal motion is affected in this way. Then—

**Problem VII.**—If there be a periodic oscillation in the apsidal motion, what effect will this have on the spectrum?

To represent such an oscillation we must write

\[
(\psi t + a \sin \zeta t) \text{ instead of } \psi t
\]

in the equations of Problem II., where

\[
\psi = 2\pi n/j \text{ and } \zeta = 2\pi q/j.
\]
This substitution being made in any of the equations of Problem II., suppose in equations (3 a), we get

\[
\begin{align*}
X_1 &= \frac{a + b}{2} \cos \left[ (\theta + \psi) t + \alpha \sin \xi t \right], \\
Y_1 &= \frac{a + b}{2} \sin \left[ (\theta + \psi) t + \alpha \sin \xi t \right].
\end{align*}
\]

To see how this will operate, imagine \( \beta \) to be the value through which \( \xi t \) passes at the instant when \( t = \tau \). Then for a short period of time after

\[
\sin \xi t = \sin \beta + \cos \beta \cdot d. \xi t
\]

\[
= \sin \beta + \cos \beta \cdot \frac{2\pi q}{j} dt,
\]

in which \( dt \) is to be regarded as equal to \( t - \tau \) for a short time after the epoch \( \tau \). Putting this into (14) we find that equations (14) during a short period furnish a line of frequency \( (m + n + \alpha \cos \beta \cdot q) \). By dividing \( j/q \) the periodic time of \( \xi t \), into equal parts; by giving to a series of \( \beta \)'s the values which \( \xi t \) has at the commencement of each of these equal intervals of time; and by then supposing that the duration of these intervals decreases while their number increases indefinitely: we find that the total effect is the limit (when \( N \) increases indefinitely) of a band of \( N \) lines of equal brightness, crowded towards the middle, and becoming more and more spaced asunder towards the edge—in other words, it is a nebulous or 'diffuse' line fading out equally* on both sides. The middle of the line has the frequency \( m + n \), and its wings extend from \( m + n + \alpha q \) on the more refrangible side, to \( m + n - \alpha q \) on the less refrangible side.

The same appearance in the spectrum would result from a periodic oscillation affecting either of the other perturbations; and in Problem IV. we have found that wings will present themselves if there is a fluctuation in the inclination of the plane of the ellipse to the invariable plane. Accordingly, nutation makes the lines diffuse, and a fluctuating inclination makes them winged.

* That is, equally, if the nutation is a mere pendulous one.
CHAPTER III.

THE PROBLEM TREATED FROM THE STANDPOINT OF THE ELECTRO-MAGNETIC THEORY OF LIGHT.

Whether we proceed under the crude dynamical hypothesis which we have hitherto adopted, or under the electro-magnetic theory to which we are now to direct our attention, we must distinguish between the motions of or in the molecules which do not affect the luminiferous æther, and certain others which set up an undulation in it—an undulation which consists of transverse oscillations under the dynamical hypothesis, but of alternations of electro-magnetic stresses under the electro-magnetic theory. Among motions of the first kind, those that do not affect the æther and are not affected by it, we are to include the following: the progressive journeys of the molecules as they dart about between the encounters; the much swifter translation which carries a molecule of the gas through the æther at the rate of 30,000 metres per second, in common with the rest of the earth; and other motions of a like kind. There are also probably motions in the molecule of a swiftly periodic kind that do not affect the æther, but there are certainly some that do, and it is these that we have to investigate.

The simplest hypothesis for our purpose is to disregard the motion of the molecule through the æther, whether that which it has in common with the earth, or that which is peculiar to it, such as its darting about in the gas. We may simplify the problem by disregarding these, and may treat the molecule as though it remained at one station in the æther, undergoing internal periodic motions, some of which are of parts that carry charges of electricity with them, and, therefore, act on the æther and are acted on by it; so that periodic motions, when set up in these parts, will cause a synchronous motion in the æther. Correspondingly, an undulation in the æther of suitable periodic time will set these parts of the molecule in motion, and through them, perhaps other parts of the molecule. The distinction between the motions which do, and the motions which do not, affect the æther, requires to be taken into account equally on the dynamical hypothesis and on the electro-magnetic theory.

To pass from the dynamical investigation to the electro-magnetic, attention must be given to Faraday's "Law of Electrolysis," which is equivalent to the statement that in electrolysis a definite quantity of electricity, the same in all cases, passes for each chemical bond that is ruptured. The author called attention to this form of the Law in a communication made to the British Association in
1874, and printed in the Scientific Proceedings of the Royal Dublin Society of
February, 1881, and in the Philosophical Magazine for May, 1881 (see pp. 385 and
386 of the latter). It is there shown that the amount of this very remarkable
quantity of electricity is about the twentieth (that is, \(1/10^{20}\)) of the usual elec-
 tromagnetic unit of electricity, \(i.e.\) the unit of the ohm series. This is the same as
three-elevenths \((3/10^{11})\) of the much smaller \(C.G.S.\) electrostatic unit of quantity.
A charge of this amount is associated in the chemical atom with each bond. There
may accordingly be several such charges in one chemical atom, and there appear
to be at least two in each atom. These charges, which it will be convenient to
call \(electrons\), cannot be removed from the atom; but they become disguised when
atoms chemically unite. If an electron be lodged at the point \(P\) of the molecule,
which undergoes the motion described in the last chapter, the revolution of this
charge will cause an electro-magnetic undulation in the surrounding \(\text{aether}\). The
only change that has to be made in our investigation to adapt it to this state
of things is to change \(\delta t\) into \((\delta t - \pi/2)\), \(i.e.\) a mere change of phase. We, in this
way, represent the fact that it is the tangential direction and velocity of the
motion of \(P\); not the direction and length of its radius vector, which determine the
direction and intensity of the electro-magnetic stresses in the surrounding \(\text{aether}\).
We have further to correct for the change of phase (about one-fourth of a vibration
period) consequent upon what takes place in the immediate vicinity of the moving
charge.

Within the molecule itself the oscillation of the permanent charge probably
causes electric displacements in other parts of the molecule; and it is possible that
it is to the reaction of these upon the oscillating charge that we are to attribute
those perturbations of which the double lines in the spectrum give evidence. They
obviously may, however, have some other source.

Beside the irremovable electric charges which electrolysis has brought to
light, and which establish the fact that some parts of the molecule behave as
perfect non-conductors, there may presumably be temporary charges in such
other parts of the molecule as conduct. This probably happens by direct electrifi-
cation of the molecule when the luminous condition of the gas is produced by
the passage of an electric current through it, and it would seem that it must also
be brought about indirectly in cases of combustion, owing to the combinations and
decompositions which then occur during which some of the permanent charges
become disguised or cease to be disguised; in either case having the effect of
charging the molecule with free electricity, positive or negative.

Now, molecules whether electrified in these ways, or by the motions set up
within the molecule developing electricity as in an influence machine, must
be expected to discharge into one another when they collide, and hence will arise
the kind of undulation in the æther which is exhibited in Hertz's experiments. The periodic time of this undulation is, as is known,

$$T = 2\pi \sqrt{\frac{I}{S}} \text{ sec } \rho,$$

where

$$\sin \rho = \frac{R^2 S}{4I},$$

$S$ being the capacity of the molecule, $I$ the co-efficient of self-induction in the current, and $R$ its resistance. It is doubtful whether $S$, $I$, and $R$ can be such as will bring the periodic time low enough to correspond to that of any of the observed lines; and even if this be the case, the discharge would probably produce only a single line in the spectrum, or a line and its harmonics. The presence of double lines affords further evidence that the observed spectrum does not arise from these Hertzian discharges, since they require as their cause some event affecting the lines which operates with a sameness in all the molecules which, we may presume, is inconsistent with the chance conditions under which discharges between molecules would take place. But the most conclusive evidence on this point is furnished by the reversal of the lines of incandescent gases when surrounded by their own vapour at a lower temperature. This phenomenon shows that the undulation created in the æther by one set of molecules is capable of effacing itself by transferring back the energy of its special oscillations to another set of the molecules that are more quiescent. This seems incompatible with the event being a Hertzian discharge between pairs of molecules, since this is not a process which would be reversed under the conditions supposed, while it does exactly agree with what would appear to be inevitable if the event is the movement of an electron in that orbit which is its natural swing.

To explain, therefore, the lines that present themselves in the spectra of incandescent gases, it is probable that we must fall back upon the motions communicated by the encounters to those non-conducting parts of the molecule in which are lodged the electrons, and upon periodic changes in the distribution of electricity in the conducting part of the molecule consequent upon the movements of these permanent charges. These will be synchronous, and will jointly excite an electro-magnetic undulation in the æther with the periodic times that they have in common.

There seems but one other point in this connexion that needs elucidation. It may be thought that with a multitude of molecules, each oscillating within itself, the external effect will be nil—that every molecule in which the point $P$ moves one way, will be counteracted by some other molecule, in which the point $P$ moves the opposite way. But this is to overlook the fact that, in addition
to molecules acting on the aether, the aether reacts on them; and thus each molecule is indirectly influenced through the aether by all its neighbours, whereby the direction and phase of its oscillations will inevitably fall into a sufficient accordance with theirs.

We may therefore freely use the whole of the investigation in the last chapter to represent what takes place under the electro-magnetic theory of light; merely remembering that $\theta t$ is now a quadrant in advance of where it was under the dynamical hypothesis, so that to represent the position of the point $P$ we must substitute $(\theta t - \pi/2)$ for $\theta t$ in all the equations of Chapter II. This, in no respect, affects any of the conclusions.

CHAPTER IV.

ANALYSIS BY FOURIER’S THEOREM.

We have hitherto treated in detail only those cases (if any such occur) in which the original motion of the electron, set up by the encounter, is a pendulous elliptic motion. But this degree of simplicity is not met with in any known spectrum. The line spectrum of hydrogen is the least complex with which we are acquainted, and the next in simplicity are the spectra of the other light monad elements, lithium, sodium, potassium, rubidium, and caesium. In the spectrum of hydrogen there is at all events one great series of lines (probably double lines), and in the spectrum of each of the others three such series are known. It becomes therefore of importance to inquire whether the entire of one of these series of lines emanates from the motion of one of the electric charges in the molecules of the gas. The following propositions, in conjunction with what has been done in the preceding chapters, lay much of the foundation for following up this inquiry.

However complex the motion of a point may be, provided it takes place in a straight line, Fourier’s theorem resolves it into pendulous elements. This is enough for the purposes of acoustics, inasmuch as the motions to be dealt with in that science are sensibly rectilinear. But it is not sufficient when dealing with the transmission of electro-magnetic stresses through the aether, since the alternations of such stresses are propagated under the laws of an undulation in which the motion of each point is restricted, not to a line but to a plane. Hence arises—

PROBLEM A.—What theorem corresponds to Fourier’s theorem when the motion takes place along any plane curve?
Here the motion is represented by

\[
\begin{align*}
x &= F_1(t), \\
y &= F_2(t),
\end{align*}
\]

where \( F_1 \) and \( F_2 \) may be any two functions. By Fourier's theorem, these become

\[
\begin{align*}
x &= A_0 + A_1 \cos \theta_1 t + A_2 \cos \theta_2 t + \ldots \\
&\quad + B_1 \sin \theta_1 t + B_2 \sin \theta_2 t + \ldots \\
y &= C_0 + C_1 \cos \theta_1 t + C_2 \cos \theta_2 t + \ldots \\
&\quad + D_1 \sin \theta_1 t + D_2 \sin \theta_2 t + \ldots 
\end{align*}
\]

where \( \theta_1 = 2\pi m_1/T, \theta_2 = 2\pi m_2/T, \ldots \) in which \( m_1, m_2, \ldots \) are positive integers when \( T \) is the periodic time (if any) of the motion, and in which \( m_1, m_2, \ldots \) are numbers of which some at least are fractions when \( T \) is not the periodic time. If the motion resolves itself into a finite number of terms, and if it is at the same time one which does not repeat itself in a period however long, some of the numbers \( m_1, m_2, \ldots \) are incommensurable. The coefficients (the \( A \)'s, \( B \)'s, \( C \)'s, and \( D \)'s), are in all cases represented by the well-known definite integrals of Fourier's theorem, and in some cases calculable from them. It should be borne in mind that a resolution effected by Fourier's theorem is unique: in every case one such resolution exists, and only one.

We shall now proceed to prove that the four terms in these series which stand in any one of the vertical columns of equations (b) represent a pendulous elliptic motion; so that equations (b) in effect resolve the original motion of equations (a), whatever be its law, into partials, each of which is a pendulous elliptic motion.

Take any vertical column, e.g. the \( k \)th—

\[
\begin{align*}
x_k &= A_k \cos \theta_k t \\
&\quad + B_k \sin \theta_k t, \\
y_k &= C_k \cos \theta_k t \\
&\quad + D_k \sin \theta_k t,
\end{align*}
\]

or, leaving the suffixes to be understood,

\[
\begin{align*}
x &= A \cos \theta t + B \sin \theta t, \\
y &= C \cos \theta t + D \sin \theta t,
\end{align*}
\]

and let us try whether we can identify it with the pendulous elliptic motion

\[
\begin{align*}
x' &= a \cos (\theta t + a), \\
y' &= b \sin (\theta t + a),
\end{align*}
\]

in the same plane, and of the same frequency.
Let $\beta$ be the angle between the axes $Ox$ and $Ox'$. Then the motion (d) referred to the axes $Ox$ and $Oy$ becomes

$$X = a \cos (\theta t + a) \cos \beta - b \sin (\theta t + a) \sin \beta,$$

$$Y = a \cos (\theta t + a) \sin \beta + b \sin (\theta t + a) \cos \beta,$$

which when expanded becomes

$$X = \cos \theta t \left( a \cos a \cos \beta - b \sin a \sin \beta \right)$$

$$- \sin \theta t \left( a \sin a \cos \beta + b \cos a \sin \beta \right),$$

$$Y = \cos \theta t \left( a \sin a \sin \beta + b \sin a \cos \beta \right)$$

$$- \sin \theta t \left( a \sin a \sin \beta - b \sin a \cos \beta \right).$$

Now, we can determine $a$, $b$, $a$ and $\beta$, so as to make

$$a \cos a \cos \beta - b \sin a \sin \beta = + A,$$

$$a \sin a \cos \beta + b \cos a \sin \beta = - B,$$

$$a \cos a \sin \beta + b \sin a \cos \beta = + C,$$

$$a \sin a \sin \beta - b \sin a \cos \beta = - D.$$  

Hence, when $a$, $b$, $a$ and $\beta$, have the values so determined, the pendulous motion represented by (d) is identical with the motion represented by (e).

Hence the theorem corresponding to Fourier's theorem is—

**Theorem A.**—Any motion of a point in a plane may be regarded as the coexistence and superposition of definite partials which are the pendulous elliptic motions determined as above, one from each of the several vertical columns of equations (b).

These elliptic partials will all be in the plane of the original motion. They will, however, in general lie in different azimuths in that plane, and be in different phases at any one time.*

What lends importance to this theorem is that the resolution effected by it in our calculations is identical with that which an undulation of electro-magnetic stresses in the open æther (as, for example, the great complex undulation which reaches our atmosphere from the sun or a star) does actually undergo when the

---

* In order to characterize the kind of motion which takes place in a partial, it is sufficient to determine three constants, viz. $a$, $b$, and $\theta$ (the axes of the ellipse and the swiftness of the motion in it). But to determine the position of $P$ at each instant, it is necessary to determine two more constants $\beta$ and $a$ ($\beta$, the azimuth of the ellipse in its plane, and $a$ the position of $P$ in it at the instant $t = 0$).

A continuous spectrum arises when the $\theta$'s of the partials are indefinitely close, a spectrum of lines when they are at intervals that can be perceived.
undulation either advances into a dispersing medium, or suffers diffraction. In the open ether the pendulous elliptic components travel at the same rate and keep together, but on entering a dispersing medium they advance with different speeds and become separated, or, if they encounter a diffraction grating they are by it sent in different directions. It is one or other of these separations that the spectroscope makes manifest to us.

But the motions of the electrons, the electric charges in the molecules of the gases, which are what excite this aetherial undulation, may be motions that are not confined to one plane. Accordingly, to study them, we must investigate—

Problem B.—What theorem corresponds to Fourier's theorem when the motion takes place along a line of double curvature?

Such a motion is in general represented by—

\[
\begin{align*}
x &= F_1(t), \\
y &= F_2(t), \\
z &= F_3(t).
\end{align*}
\]

When referred to the rectangular axes Ox, Oy, Oz. These when expanded by Fourier's theorem become—

\[
\begin{align*}
x &= A_0 + A_1 \cos \theta_1 t + A_2 \cos \theta_2 t + \ldots \\
&\quad + A'_1 \sin \theta_1 t + A'_2 \sin \theta_2 t + \ldots \\
y &= B_0 + B_1 \cos \theta_1 t + B_2 \cos \theta_2 t + \ldots \\
&\quad + B'_1 \sin \theta_1 t + B'_2 \sin \theta_2 t + \ldots \\
z &= C_0 + C_1 \cos \theta_1 t + C_2 \cos \theta_2 t + \ldots \\
&\quad + C'_1 \sin \theta_1 t + C'_2 \sin \theta_2 t + \ldots
\end{align*}
\]

Let us take any vertical column from these, e. g.

\[
\begin{align*}
x_k &= A_k \cos \theta_k t + A'_k \sin \theta_k t, \\
y_k &= B_k \cos \theta_k t + B'_k \sin \theta_k t, \\
z_k &= C_k \cos \theta_k t + C'_k \sin \theta_k t,
\end{align*}
\]

or, leaving the suffixes to be understood,

\[
\begin{align*}
x &= A \cos \theta t + A' \sin \theta t, \\
y &= B \cos \theta t + B' \sin \theta t, \\
z &= C \cos \theta t + C' \sin \theta t,
\end{align*}
\]

of which (by Problem A) the first two are equivalent to the elliptic motion,

\[
\begin{align*}
x' &= u \cos (\theta t + \epsilon), \\
y' &= v \sin (\theta t + \epsilon),
\end{align*}
\]
in the plane of xy, and with its axis major inclined at an angle \( \xi \) to Ox: \( u, v, e \), and \( \xi \) being determined in the same way as \( a, b, \alpha \) and \( \beta \) in Problem A.

Thus, taking \( O'x', O'y' \), and \( Oz \) as axes, we find the motion represented by

\[
\begin{align*}
x' &= u \cos (\theta t + e), \\
y' &= v \sin (\theta t + e), \\
z &= C \cos \theta t + C' \sin \theta t.
\end{align*}
\]

Let us, by equating coefficients of \( \cos \theta t \) and of \( \sin \theta t \), determine \( M \) and \( N \), such that

\[
C \cos \theta t + C' \sin \theta t = M \cos (\theta t + e) + N \sin (\theta t + e),
\]

whereby equations \((b_4)\) become

\[
\begin{align*}
x' &= u \cos (\theta t + e), \\
y' &= v \sin (\theta t + e), \\
z &= M \cos (\theta t + e) + N \sin (\theta t + e).
\end{align*}
\]

Now, it is possible to identify this with the pendulous elliptic motion

\[
\begin{align*}
x'' &= a \cos (\theta t + e + \alpha), \\
y'' &= b \sin (\theta t + e + \alpha), \\
Z_i &= M \cos (\theta t + e) + N \sin (\theta t + e),
\end{align*}
\]

having the same frequency, and lying in a position which can be determined. For—

Let \( OX \) be the intersection of the plane \( x'y' \) (which is identical with \( xy \)), with the plane \( x''y'' \); and let \( \beta \) be the angle \( x''O'X \) and \( \gamma \) the angle \( x'OX \). Then equations \((b_4)\) are equivalent to

\[
\begin{align*}
X_1 &= u \cos (\theta t + e) \cos \gamma - v \sin (\theta t + e) \sin \gamma, \\
Y_i &= u \cos (\theta t + e) \sin \gamma + v \sin (\theta t + e) \cos \gamma, \\
Z_i &= M \cos (\theta t + e) + N \sin (\theta t + e),
\end{align*}
\]

the two former being in the plane \( xy \), and \( X_i \) being along \( OX \), the line of intersection.

Again, equations \((c_i)\) are equivalent to

\[
\begin{align*}
X'' &= a \cos (\theta t + e + \alpha) \cos \beta - b \sin (\theta t + e + \alpha) \sin \beta, \\
Y'' &= a \cos (\theta t + e + \alpha) \sin \beta + b \sin (\theta t + e + \alpha) \cos \beta,
\end{align*}
\]

in the plane \( x''y'' \), \( X'' \) being along \( OX \), the line of intersection. This, if \( \omega \) be the angle at which the planes \( xy \) and \( x'y'' \) are inclined to one another, is equivalent to—

\[
X_2 = X'' \text{ along the line of intersection,} \\
Y_2 = Y'' \cos \omega, \text{ in the plane } xy, \text{ and perpendicular to the line of intersection.} \\
Z_2 = Y'' \sin \omega, \text{ along } Oz.
\]
Thus the motion \( (e_2) \) is equivalent to

\[
\begin{align*}
X_2 &= a \cos (\theta t + \epsilon + \alpha) \cos \beta - b \sin (\theta t + \epsilon + \alpha) \sin \beta, \\
Y_2 &= [a \cos (\theta t + \epsilon + \alpha) \sin \beta + b \sin (\theta t + \epsilon + \alpha) \cos \beta] \cdot \cos \omega, \\
Z_2 &= [a \cos (\theta t + \epsilon + \alpha) \sin \beta + b \sin (\theta t + \epsilon + \alpha) \cos \beta] \cdot \sin \omega,
\end{align*}
\]

which we shall identify with the motion \( (b_2) \) if we can determine \( a, b, \alpha, \beta, \gamma, \) and \( \omega, \) so as to make the coefficients of \( \cos (\theta t + \epsilon) \) and \( \sin (\theta t + \epsilon) \) identical in equations \( (b_2) \) and \( (e_2). \)

Now, the equations \( (e_2) \) are identical with

\[
\begin{align*}
X_2 &= \cos (\theta t + \epsilon) \cdot k - \sin (\theta t + \epsilon) \cdot p, \\
Y_2 &= [\cos (\theta t + \epsilon) \cdot q - \sin (\theta t + \epsilon) \cdot r] \cdot \cos \omega, \\
Z_2 &= [\cos (\theta t + \epsilon) \cdot q - \sin (\theta t + \epsilon) \cdot r] \cdot \sin \omega,
\end{align*}
\]

in which

\[
\begin{align*}
k &= a \cos \alpha \cos \beta - b \sin \alpha \sin \beta, \\
p &= a \sin \alpha \cos \beta + b \cos a \sin \beta, \\
q &= a \cos \alpha \sin \beta + b \sin \alpha \cos \beta, \\
r &= a \sin \alpha \sin \beta - b \cos \alpha \cos \beta.
\end{align*}
\]

Identifying the coefficients in \( (b_2) \) and \( (e_2) \) we find that the equations to be satisfied are—

\[
\begin{align*}
k &= u \cos \gamma, \\
p &= v \sin \gamma, \\
q \cos \omega &= u \sin \gamma, \\
r \cos \omega &= -v \cos \gamma, \\
q \sin \omega &= M, \\
r \sin \omega &= -N.
\end{align*}
\]

From \( (e_2) \) and \( (e_2) \), we find that

\[
\tan \omega = \frac{M}{u \sin \gamma}.
\]

Similarly, from \( (e_2) \) and \( (e_2) \) we find that

\[
\tan \omega = \frac{N}{v \cos \gamma}.
\]

Equating these, we find that

\[
\tan \gamma = \frac{v M}{u N},
\]

which determines \( \gamma. \) Having found \( \gamma, \) equations \( (e_1) \) and \( (e_2) \) determine \( k \) and \( p, \) and equation \( (f_1) \) determines \( \omega; \) and having found \( \gamma \) and \( \omega, \) either equations \( (e_4) \)
and \((a_3)\) or equations \((e_3)\) and \((e_5)\) will determine \(q\) and \(r\), and the determinations in whichever way made are identical. Hence \(k, p, q,\) and \(r\) become known, and equations \((d)\) enable us from them to determine \(a, b, \alpha\) and \(\beta\).

Hence, the form \((a, b)\), the phase \((a + \epsilon)\), and the position \((\beta, \gamma, \omega)\), of the elliptic motion, can be determined in terms of \(u, v, M, N,\) and \(\epsilon\), of equations \((b)\); and thus, through them, the elliptic motion is completely determined in terms of the coefficients \(A, A', B, B', C, C'\) and \(\theta\), of one of the vertical columns of equations \((a)\). We accordingly arrive at the conclusion that—

Theorem B.—Any motion of a point in space may be regarded as the coexistence and superposition of one definite set of partials which are the pendulous elliptic motions determined as above from the several vertical columns of equations \((a)\).

These partials will, in general, lie in different planes, and be in different phases. The periodic time of each will be the periodic time of that vertical column of equations \((a)\) from which it is derived. Seven constants are associated with each partial—of these, \(a, b,\) and \(\theta\) give the ellipse and the swiftness of motion in it, \(\gamma\) and \(\omega\) give the position of its plane, \(\beta\) gives its position in that plane, and finally \((a + \epsilon)\) gives the position in the ellipse at which \(P\) was at the instant \(t = 0\).

Before proceeding further it may be well to refer again to an objection that is likely to be felt. It may at first sight seem very improbable that within a molecule there can be parts of it moving so freely as to describe definite orbits that suffer steady perturbation. But we must remember, as was pointed out on p. 564, that in dealing with the internal motions of molecules we have reached a stage where there is no longer any degradation of motions such as that effected by friction or viscosity—in fact where the motions, whatever they are that occur in a molecule during its flights, are performed without loss of energy other than that communicated to the æther—with no loss whatever arising from the dynamical relations of the parts of the molecule to one another.

The only alternative hypothesis is that the molecules are rigid. Here we might have a rotation, and if the three principal moments of gyration were unequal we should have the instantaneous axis describing an elliptic cone, and so supplying the condition for double lines. But, nevertheless, the hypothesis is inadmissible, as it would necessitate a constancy in the rotation which is inconsistent with the varying brightness of the spectrum at different temperatures, and which indeed independently of this could not survive the collisions that are going on, as is evident from dynamical considerations. We may therefore adhere with confidence to the hypothesis made in this Memoir, that there are relative motions going on within the molecules which are unimpeded except by the æther.
CHAPTER V.

ILLUSTRATIONS.

When a chord is played by an orchestra, a very complicated undulation spreads around it through the air. This involved motion admits of two successive resolutions into simpler elements, first by regarding it as the coexistence and superposition of undulations emanating from the several instruments each of which by itself would produce the effect on the ear of a musical note; and next by the further resolution of the note emitted by each separate instrument into its pendulous elements whose coexistence is what gives to the tone of that instrument its special quality. So long as the undulation advances through the air, these elements are not separated from one another; but their presence is indicated analytically in the fullest detail by Fourier’s theorem, and the ear of a highly trained musician is a means by which they may in practice be partially distinguished. Such a person can completely effect the first resolution, i.e. can distinguish each separate note, and can imperfectly effect the second resolution, i.e. he can distinguish the qualities or clangs of these separate notes; but his ear is powerless to complete the resolution by distinguishing the individual partials or pendulous elements, whose presence is what determines the distinctive sound of each instrument. Now that which the ear does imperfectly in the case of sound the spectroscope does fully in the case of light.

In this comparison between light and sound, each molecule of the gas corresponds to the entire orchestra; and the orbits described within it by its several electrons are what correspond to the vibrations of the sounding-boards, columns of air, &c., of the instruments, these being the parts of the orchestra which act directly on the surrounding medium. The undulation in the luminiferous æther which emanates from a molecule of the gas corresponds to the waves that fill the atmosphere when a chord is being played by the instruments of the orchestra. That we can resolve this into the notes emitted by the individual instruments corresponds to our being able in some cases to divide the lines of the spectrum of a gas into groups, each of which may be attributed to the motion of one of its electrons. The patterns which we may observe in these groups of lines correspond to the clangs or qualities of the notes of the orchestra; and, finally, the individual lines themselves supply us directly with the intensities and periodic times of the individual partials which are the ultimate elements into which Fourier’s theorem resolves every undulation of the æther, however complex.
The "partials" or ultimate elements into which a sound-wave in air can be resolved take the very simple form—

\[ x = a \cos \theta t. \]

They are pendulous vibrations in a straight line, and we may regard each of them as fully characterized if we can ascertain the values of its \( a \) and \( \theta \). These are furnished by the intensity and pitch of the corresponding simple sound, which can be determined experimentally by the use of resonators.

This simplest form is also the form of the ultimate elements into which the motions going on in the instruments of the orchestra are to be revolved. They are all partials of the form \( x = a \cos \theta t \), fully characterized when we can determine \( a \) and \( \theta \).

If, however, we want to make out what is the actual motion that is going on, it is not sufficient to characterize its individual partials correctly, it is also necessary to be able to combine them: and to do this we must know the phases in which they all have been at some one instant of time. Now it is still a moot point whether we can elicit any information about the phases from an analysis of the resultant sound: we certainly cannot elicit enough of information in this way. To acquire it we must have recourse to a study of the instruments from which the sound has come, and, unfortunately, in the case of light we are in the predicament of not being able to do what corresponds to this.

Neither are the partials of the æthereal undulation so simple as in the case of sound. Each æthereal partial is a pendulous elliptic revolution in the plane of the wave, of the form

\[ x = a \cos \theta t, \quad y = b \sin \theta t, \]

or rather it is some change of varying electro-magnetic stresses that follows this law. We may, however, for clearness and convenience, continue to speak of it as a motion in the plane of the wave, it being understood that what is meant is some change in the æther which follows the same law as the motion. Now to characterize the above partial of such a motion, three quantities are required, \( a \), \( b \), and \( \theta \); and what we can observe by separately examining its spectral line is not enough to determine three quantities. The position of the line on the map of oscillation-frequencies tells us the value of \( \theta \), its intensity determines \( a^2 + b^2 \), and this is all that is given us by the examination of a single line. We have enough, however, if we independently know of some other equation between \( a \) and \( b \). Thus from Chap. II., we know that \( b = + a \) for one of the two constituents of a double line, and that \( b = -a \) for the other. In the case of double lines, therefore, the two corresponding partials of the motion in the æther are completely determined. Again, if satellites arise in any of the ways pointed out in Chap. II., when not due to circular, they are due to rectilinear vibrations. Here again, since \( b = 0 \), the partial
may be completely determined by observation of the line. Now it is probable that all the lines of the spectra of H, Li, Na, K, Rb, and Cs fall into one or other of these categories, and if this is so, all the partials of the æthereal undulation causing these spectra can be determined by observations with the spectroscope.

We have next to consider the motions going on in one of the molecules of the gas. These correspond to the motions going on in an orchestra; and of them the only ones to which we have a direct clue are the motions of the electrons themselves, since we can only work back from the effect on the æther and these are the only motions in the molecules that act directly on the æther. They correspond to the motions of the sounding-boards of the stringed instruments and the columns of air in the wind instruments of the orchestra, as these are what act directly on the surrounding atmosphere.

Here, again (see last chapter), the motion of the electron may be resolved into elliptic partials of the form,

\[ x = a \cos \theta t, \quad y = b \sin \theta t; \]

but as the electron is not necessarily confined to one plane, we must remember that its path may be a curve of double curvature, in which case the elliptic partials will lie in different planes, see p. 591.

---

CHAPTER VI.

APPLICATIONS.

We may, however, best form a judgment as to how far observations with the spectroscope will carry us by studying some one spectrum. The spectrum of any of the above-mentioned monads would do, but amongst them that of sodium seems the best adapted for our purpose.

Professor Rydberg has collected and analyzed the principal observations on this spectrum, and I follow the selection from amongst them which he made, adding to them the determinations since made by Professors Kayser and Runge. Thirty-five lines, thirteen double lines and nine others, had been observed.* Professor Rydberg conjectures that they are all, except one satellite, double. In this connexion it should be noted that, in accordance with the analysis given above on page 572, even where there is the apsidal motion which produces double lines, one of a pair may be of cypher intensity, and, accordingly, the line as it appears in

* Two others more refrangible, and belonging to series \( F \), have since been announced by Professors Kayser and Runge.
the spectrum may be single. This will happen whenever the corresponding pendulous component of the dominant motion of the electron is circular.

Of the thirty-five known lines, Professor Rydberg arranges thirty-two in the three following series,* and the three remaining lines he supposes to be satellites of the third and fourth terms of series $D$. We must, however, here be on our guard against lines that are intruders, and owe their presence to impurities in the sodium. We should also bear in mind that they or some of them may be sodium lines which are members of a series, if such exists, the rest of which lies beyond the part of the spectrum that has been explored.

Using the language of acoustics, we may regard the whole spectrum as an optic chord which is being played by the molecules of sodium. Each of Rydberg's series will then be one of the notes of this chord, and the individual lines will be the partials of these notes. The three optic notes are—

Series $P$ (the principal series) of lines that form a definite pattern, and in each pair of which the more refrangible line is the stronger.

Series $P$.

<table>
<thead>
<tr>
<th>Term of Series according to Rydberg</th>
<th>Recorded character of lines.</th>
<th>Kayser and Runge’s Measures (on Rowland’s Scale).</th>
<th>Earlier determinations of $\lambda$ (on Ångström’s Scale).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\lambda = \frac{T}{\mu}$ $\kappa = \mu \cdot N$</td>
<td>$\lambda$ $\mu$ $\kappa$ $\lambda$</td>
</tr>
<tr>
<td>First, ...</td>
<td>Easily reversed, ... ...</td>
<td>5890·16 169·602 172 5890·13 Ångström.</td>
<td>5890·12 Ångström.</td>
</tr>
<tr>
<td>Second, ...</td>
<td>Easily reversed, ... ...</td>
<td>3302·07 302·749 3300·1 3300·8 Cornu.</td>
<td>3301·2 Cornu.</td>
</tr>
<tr>
<td>Third, ...</td>
<td>Easily reversed, ... ...</td>
<td>2852·91 359·519 2853·3 Living and Dewar.</td>
<td>2853·3 Living and Dewar.</td>
</tr>
<tr>
<td>Fourth, ...</td>
<td>Easily reversed, ... ...</td>
<td>2689·46 373·079 2689·0 Living and Dewar.</td>
<td>2670·0 Living and Dewar.</td>
</tr>
<tr>
<td>Fifth, ...</td>
<td>Easily reversed, ... ...</td>
<td>2593·98 385·508 2593·3 Living and Dewar.</td>
<td>2593·3 Living and Dewar.</td>
</tr>
<tr>
<td>Sixth, ...</td>
<td>Easily reversed, ... ...</td>
<td>2543·85 333·105 2543·85 Kayser and Runge.</td>
<td>2543·85 Kayser and Runge.</td>
</tr>
<tr>
<td>Seventh, ...</td>
<td>Easily reversed, ... ...</td>
<td>2512·23 398·653 2512·23 Kayser and Runge.</td>
<td>2512·23 Kayser and Runge.</td>
</tr>
</tbody>
</table>

* Professors Kayser and Runge, using a different formula from Professor Rydberg's, distribute them into the same three series.
Stoney—Cause of Double Lines in Spectra.

Series $D$ of lines that are diffuse, that form a definite pattern when plotted down on a map, and in each pair of which the less refrangible line is the stronger.

Series $D$.

<table>
<thead>
<tr>
<th>Term of Series according to Rydberg</th>
<th>Recorded character of lines</th>
<th>Kayser and Runge's Measures (on Rowland's Scale)</th>
<th>$N$</th>
<th>Earlier determinations of $\lambda$ (on Angström's Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second, ...</td>
<td>--</td>
<td>$\lambda = \frac{T}{\mu}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\kappa = \mu \cdot N$</td>
<td>179</td>
<td>$8199$ { Abney.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8187</td>
<td></td>
</tr>
<tr>
<td>Third, ...</td>
<td>Nebulous towards the red, ..</td>
<td>5685:26</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5682:90</td>
<td>175:891</td>
<td>$8163$ { Tholén.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>166</td>
<td></td>
</tr>
<tr>
<td>Satellites (?) ...</td>
<td>Nebulous towards the violet,</td>
<td>5675:92</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5670:40</td>
<td>176:183</td>
<td>$5673:6$ { Living and Dewar.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>171</td>
<td></td>
</tr>
<tr>
<td>Fourth term and Satellite (?) ...</td>
<td>Nebulous towards the red, ..</td>
<td>4982:53</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4979:30</td>
<td>200:661</td>
<td>$4990:5$ { Living and Dewar.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>170</td>
<td></td>
</tr>
<tr>
<td>Fifth, ...</td>
<td>Nebulous towards the red, ..</td>
<td>4669:4</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4666:2</td>
<td>214:160</td>
<td>$4663:7$ { Living and Dewar.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>193</td>
<td></td>
</tr>
<tr>
<td>Sixth, ...</td>
<td>Very nebulous, ..</td>
<td>4500:0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4494:3</td>
<td>224:222</td>
<td>$4496:4$ { Living and Dewar.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>282</td>
<td></td>
</tr>
<tr>
<td>Seventh, ...</td>
<td>Nebulous, ..</td>
<td>4595:7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4590:7</td>
<td>227:599</td>
<td>$4590$ { Living and Dewar.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>Eighth, ...</td>
<td>Part of a band, ..</td>
<td>4325:7</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>231:177</td>
<td></td>
<td>$4325$ { Living and Dewar.</td>
</tr>
</tbody>
</table>

Series $S$ of lines that are sharp, that form a definite pattern, and in each pair of which the less refrangible line is the stronger—
Stoney—Cause of Double Lines in Spectra.

Series S.

<table>
<thead>
<tr>
<th>Term of Series according to Rydberg</th>
<th>Recorded character of lines</th>
<th>Kayser and Runge’s Measures (on Rowland’s Scale)</th>
<th>Earlier determinations of $\lambda$ (on Ångström’s Scale).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\lambda = T/\mu$</td>
<td>$\kappa = \mu \cdot N$</td>
</tr>
<tr>
<td>Second, ...</td>
<td></td>
<td>(11421·9)</td>
<td>87·550</td>
</tr>
<tr>
<td>Third, ...</td>
<td>Slightly nebulous towards the red</td>
<td>6161·15</td>
<td>162·307</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6164·62</td>
<td>162·480</td>
</tr>
<tr>
<td>Fourth, ...</td>
<td>Slightly nebulous on both sides,</td>
<td>5153·72</td>
<td>194·035</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5149·19</td>
<td>194·206</td>
</tr>
<tr>
<td>Fifth, ...</td>
<td>Slightly nebulous on both sides,</td>
<td>4752·19</td>
<td>210·429</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4748·36</td>
<td>210·399</td>
</tr>
<tr>
<td>Sixth, ...</td>
<td>Slightly nebulous on both sides,</td>
<td>4546·03</td>
<td>219·672</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4542·75</td>
<td>220·131</td>
</tr>
<tr>
<td>Seventh, ...</td>
<td>Sharp, ...</td>
<td>(4423·7)</td>
<td>226·555</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4420·2)</td>
<td>226·234</td>
</tr>
<tr>
<td>Eighth, ...</td>
<td>Part of a band, ...</td>
<td>(4343·7)</td>
<td>230·219</td>
</tr>
</tbody>
</table>

In these Tables—

$\lambda$ (the wave-length in air, measured in tenthet-metres) is given by observation.

$\kappa$ (the “inverse wave-length,” the number of waves in the tenth of a millimetre in air) = $10^6/\lambda$.

$T$ (the periodic time of the oscillation measured in micro-jots) = $\mu \lambda$.

$\mu$ being the index of refraction of air for that wave-length.

$N$ (the “oscillation-frequency,” i.e. the number of oscillations in each jot of time) = $\kappa/\mu$.

$\Delta N$ (the interval between the constituents of a double line on a map of oscillation frequencies) = $\Delta \kappa/\mu$.
The numbers in brackets are determinations not made by Kayser and Runge. They are the earlier determinations reduced to Rowland's scale.

An accurate determination of the values of $\mu$ throughout the spectrum is very much wanted. However, so far as $\Delta N$ is concerned, $\mu$ differs so little from unity that $\Delta N$ need not be distinguished from $\Delta \kappa$, until much more refined observations are made than those hitherto recorded.

These three optic notes $P$, $D$, and $S$, with possibly a fourth one (the existence of which there is some slender ground to suspect), make up the optic chord emitted by the molecules of sodium. Nor is the case of sodium an isolated one: all the other light monad elements, Li, K, Rb, Cs, emit optic chords of essentially the same character, consisting of three notes $P$, $D$, and $S$, closely resembling those of sodium in many important respects.

The optical clang of these notes—the relation in which their partials stand to one another—may be roughly exhibited to the eye by plotting them down on separate maps of oscillation-frequencies, when the pattern which the lines make becomes conspicuous. The scale of the diagram is too small to show that any of the lines are double. In fact, most of them are so (see foregoing Tables).

<table>
<thead>
<tr>
<th>$\lambda = \frac{T}{\mu}$</th>
<th>3000</th>
<th>2000</th>
<th>1000</th>
<th>800</th>
<th>600</th>
<th>400</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\kappa = \mu N$</td>
<td>400</td>
<td>300</td>
<td>200</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Series P.**

**Series D.**

**Series S.**


The spectrum as seen has the much more disorderly appearance which would result from plotting them all down on one map.

Professor Rydberg is of opinion that the value of $\Delta \kappa$ (the interval between the constituents of each pair) is the same in all the pairs of sodium, and that the recorded discrepancies are due to the roughness of the observations. This is a matter that careful observations will decide. Meanwhile we are concerned with studying the *inferences* that can be drawn; and in order to do this it will be convenient to take series $S$ first.
Series S.

S (a). If, as appears to be the case, Series S consists of double lines none of which has a satellite midway between its components, it follows from our investigation that—

The path of the electron, from which this series arises, is a plane curve.

S (b). If further, as Professor Rydberg supposes, the Δκ's (or rather the ΔN's, which are practically undistinguishable from the Δκ's) are identical in the several double lines of the series, it will follow that—

The dominant orbit of the electron (as started by the last encounter with another molecule) is affected during the subsequent flight of the molecule by an apsidal perturbation, which carries the orbit as a whole round in its own plane, without altering its form.

S (c). If, moreover, as Professor Rydberg concludes from the observations, the less refrangible line of each of the pairs is the brighter, it will follow that—

The elliptic partials of which the undisturbed orbit consists are all described in the same direction, and that this direction is the reverse of that in which the apsidal motion takes place.

S (d). No satellites such as those described in Problem III., p. 576 have been recorded in connexion with the lines of this series. If further observation establishes the fact that none such exist, it will follow that—

The perturbing forces do not occasion any precession.

S (e). Professor Rydberg concludes from the observations that Δκ for this series = 0.146. The correction which should be applied to this to allow for the dispersion of the air is inappreciable, so that we may take 0.146 as the value of ΔN, the difference of the oscillation-frequencies of the two rays. Now, by Problem II., n (the frequency of apsidal circuits) = \( \frac{1}{2} \Delta N \). It is therefore 0.073 or nearly 1/14. If this determination is correct it follows that—

One apsidal circuit lasts during 14 jots of time; so that about 30 of these will on the average be described during each flight of the molecule between its encounters.

S (f). Meanwhile a vast number of revolutions in the elliptic orbits of the partials will have taken place, ranging from 1226 during each of the 30 apsidal circuits in the case of the least refrangible of the observed double lines of the
series, to 3223 revolutions during each apsidal circuit in the most refrangible of the observed pairs. Exact information on these points will be obtainable if adequate observations can be made.

$S(g)$. The actual form of the elliptic orbit of each of the partials can be ascertained from observations on the brightness of the lines. See below, p. 603.

This is a considerable body of information about the motion in the molecules which causes series $S$, all of which is within our reach if adequate observations can be made.

Series D.

When we turn to the series of diffuse lines, we find that it resembles series $S$ in most respects, with, however, three notable points of difference:—the lines are brighter in series $D$ than in series $S$; they are diffuse instead of sharp; and some satellites (or supposed satellites) are present.

That the lines are brighter betokens that the partials of the primary motion of the $D$ electron are motions in larger ellipses than those of the $S$ electron; and how much larger may be ascertained so soon as measures of their relative brightnesses shall have been made. As to satellites, three supposed satellites are recorded, one apparently midway between the lines of that which Professor Rydberg regards as the fourth pair of the series. If, when adequate observations are made, it is found to be really midway between them, it will indicate that the corresponding partial lies in a plane which is inclined to the plane of the apsidal motion at an angle which can be determined so soon as the relative brightnesses of the three lines (the double line and its satellite) shall have been measured. See Corollary, * p. 577.

No similarly placed satellites are recorded of the other terms of series $D$. If upon an adequate scrutiny it is found that there are none such, it will indicate that all the partials of the primary motion, except one, lie in the plane of the apsidal motion. But as there is one which does not lie in that plane, the primary motion of electron $D$ must be a curve of double curvature.

Professor Rydberg thinks the observations warrant the conclusion that $\Delta \kappa$ is the same in all the pairs of this series, and even that it is the same in all the three series. If it has the same value in all the terms of series $D$, it will indicate that the primary motion of electron $D$ is in an orbit of double curvature which, without changing its form, shifts round in a definite plane (which is the plane of all but one of its partials) with an apsidal motion of which the frequency is $\Delta \kappa / 2$.

* What it is here convenient to regard as apsidal motion in a plane inclined to the plane of the partial, is identical with that which in the Corollary (p. 577) is perhaps more accurately described as precessional motion unaccompanied by apsidal motion.
Finally the lines are diffuse. If it be further the case that they are similarly diffuse, and that the thicknesses of the lines (when plotted down on a map of oscillation-frequencies) are everywhere the same, we must attribute the diffuseness to a common cause, which may be that the apsidal motion of the dominant orbit of electron $D$ is not a shifting of the orbit with uniform angular motion, as it is in the case of electron $S$, but that there is a subsidiary perturbation of this motion which bears to it the same relation that nutation does to precession in the rotation of the earth. The oscillation-frequency of this nutation can be determined by measuring the thickness of the lines. See p. 581. As the lines are found to be more winged on their less refrangible side, the subsidiary perturbation that causes them is more complex than a mere pendulous oscillation; but until all that observation can tell us is known it would be useless to search further for the cause.

I have not taken into account the two lines which are close to the third term of series $D$, and which Professor Rydberg regards as satellites to that term. Professors Kayser and Runge conjecture that they do not belong to any of the series $P, D$ and $S$, but that they are the only visible term of a fourth series of which the rest lies beyond the parts of the spectrum that have been explored; and they point out in support of their view that the constituents of this pair are winged towards the violet, while all the lines that are known to belong to series $D$ are winged towards the red. Their positions forbid our attributing them to the circumstances which may produce quadruple lines sketched out in Problems V. and VI. However, we shall be in a better position to deal with this group of four lines when more is known of their distances and intensities.

Series $P$.

The remaining lines of sodium that have been observed, including the great yellow double line, form another natural group which Professor Rydberg calls the principal series. All but one of the terms of this series are of high refrangibility. Some of them are known to be double lines; in others only a single line is (as yet) recorded. If they turn out to be single, they probably arise from partials that are circular. The recorded observations upon the spectra of sodium, potassium, and rubidium show that $\Delta \kappa$ is not the same in all the pairs of series $P$, which indicates that the perturbing forces acting on Electron $P$ are such as to induce different rates of apsidal shift upon the several partials of its dominant motion. Accordingly, the dominant orbit undergoes a change of form as well as of size and position during the flight of the molecule. The double lines of series $P$ are characterized by having their more refrangible constituent the brighter, in which respect they differ from the double lines of series $D$ and $S$. It
follows that the apsidal motion in series \( P \) is in the same direction as the revolutions in the partials, whereas in series \( D \) and \( S \) it is in the opposite direction. In most other respects the analysis of this series is much the same as that which has been applied to series \( S \); and any further separate treatment of series \( P \) as a whole is premature till more accurate observations shall have been made.

But the great yellow sodium line which is the first term of the series, and which corresponds to the Fraunhofer line \( D \) in the solar spectrum, has been more carefully observed than any other of the sodium lines, and is on this account the best in which to illustrate the extent of the information which can be elicited from observations on a double line in the spectrum.

For this investigation it is best to use the wavelengths-in-air of Professor Rowland's great map of the Solar Spectrum issued in 1888. Reading from it, the wavelengths-in-air of the two \( D \) (sodium) lines are—

\[
\lambda_1 = 5896.15 \text{ tenthet-metres}, \\
\lambda_2 = 5890.20 \text{ tenthet-metres}.
\]

Taking the reciprocals of these, we find the number of waves in the tenth of a millimetre in air to be

\[
\kappa_1 = 169.602, \\
\kappa_1 = 169.773;
\]

multiplying the former, and dividing the latter, by \( 1.000295 \) (Ketteler's value for \( \mu \), the index of refraction of air, for this part of the spectrum, Phil. Mag., Nov., 1866, p. 341), we find for the wavelength in vacuo, which is the same as the periodic time expressed in micro-jots—

\[
T_1 = \mu \lambda_1 = 5897.89 \text{ micro-jots}, \\
T_2 = \mu \lambda_2 = 5891.95 \text{ micro-jots};
\]

and for the number of waves in the tenth of a mm. in vacuo, which is the same as the frequency of the undulation of the aether in each jot of time—

\[
N_1 = \kappa_1/\mu = 169.552 \text{ in each jot}, \\
N_2 = \kappa_2/\mu = 169.723 \text{ in each jot}.
\]

Now by Problem II., p. 572, \( N_1 = m - n \), \( N_2 = m + n \), where \( m \) and \( n \) are respectively the frequencies of the revolution of the electron in its ellipse, and of a complete circuit of the apsidal motion. Hence—

\[
m (\text{the number of elliptic revolutions in each jot}) = \frac{N_1 + N_2}{2} = 169.637, \\
n (\text{the number of apsidal circuits in each jot}) = \frac{N_2 - N_1}{2} = .0855.
\]
From these values it appears that the partial which causes the great yellow double line of sodium is one in which the electron makes \( m/n = 1984 \) elliptic revolutions, while the apsidal motion carries the ellipse once round. An apsidal circuit is completed in \( 1/n = 11.7 \) jots. And there is time for about 420 \( n = 36 \) of these complete apsidal circuits to take place during the average flight of a molecule between two consecutive encounters, assuming this journey to occupy about 420 jots.

The more refrangible of the two lines is known to be the brighter; and I hope soon to have the means of making a good determination of the ratio of their brightnesses. Meanwhile the best estimate I can at present make gives this ratio as lying somewhere between 3:2 and 4:3. Now these numbers are nearly in the ratios of 36:25 and 49:36. We may assume, therefore, that \((a+b)^2:(a-b)^2\) lies somewhere between these ratios, and that, therefore, \(a:b\) lies somewhere between \(11:1\) and \(13:1\). Accordingly the partial in this case is a long-shaped ellipse, in form somewhere between the two ellipses delineated in the figure. Round

\[ \text{Fig. 13.} \]

this ellipse the electron travels 1984 times while the ellipse shifts gradually once round in the same direction, and something like 36 of these slow apsidal circuits are performed during each rectilinear flight of the molecule. These are the events that occur in the partial which gives rise to the great yellow double line of sodium; and an equal amount of information may be obtained in the case of every other double line that can be observed with the requisite accuracy.

It has been mentioned that the three series \( P, D, \) and \( S \) appear in the spectra of all the light monad elements, except hydrogen, viz. of Li, Na, K, Rb, and Cs; and it may be added that they are found in positions in the spectrum of progressively lower refrangibility in the order in which the elements are named, \( i.e. \) in the order of their atomic weights. Another remark that should be made is, that when we compare the spectra of these elements with one another the value of \( \Delta \kappa \) is found to increase with the atomic weight, showing that the apsidal motion is swifter, and, therefore, that the perturbing force is stronger in the more massive molecules. A series, very much like one of the foregoing, is found in the spectrum of hydrogen, but it is in a situation of too low refrangibility to be any one of these in the case of an element with such low atomic weight.*

* One is almost tempted to conjecture that all the light monads, including hydrogen, have similar spectra, and that there are four series in each, \( H, P, D, \) and \( S \), of which \( H \) appears in the spectrum of

\[ \text{trans. roy. dub. soc., n.s. vol. iv., part xi.} \]
The spectra of the heavier monads, Cu, Ag, and Au, have not been sufficiently explored to be used here for purposes of illustration. They appear to consist of double lines, one of the constituents of which is often faint, and has been recorded as a satellite, indicating that the elliptic partials in these cases are open ellipses approaching in form to the circle. In the spectra of elements of higher atomicity triple lines present themselves, the discussion of which lies beyond the scope of the present Paper.*

It appears from the investigation developed in this Paper, that when the lines of a spectrum are double, it is possible to extract from the observations a great deal of information as to each of the elliptic motions which, when put together, make up the actual motion of the electron. It remains to consider whether it is possible to combine them, and so to ascertain what the actual motion is.

Where, as in the case of hydrogen, such a law as Balmer's can be empirically obtained, there can be no doubt that all the lines (or pairs of lines) connected by so explicit a law, arise from the successive partials of the actual motion of one electron. Neither can there be a reasonable doubt where, by graphical processes or by using approximate empirical formulae like that of Professors Kayser and Runge or that of Professor Rydberg, it is found possible to pick out the lines belonging to a natural series, especially when, as generally happens, the lines so indicated are found by observation to have characteristics in common. The whole of such a series we may with confidence refer to the motion of one of the electrons in the molecules of the gas. In both these cases observations with the spectroscope will give much information about the several partials of the motion of the electron.

But all this information falls short of being sufficient to enable us to give hydrogen, but has not yet been detected in the spectra of the others because of its very low refraction in them, and of which P, D, and S lie so far in the ultra-violet in the spectrum of hydrogen that they have not yet been observed.

* In the present Memoir we are dealing only with perturbing forces that are feeble. If the perturbing forces were comparable with the forces which produce the orbit which we select as the dominant orbit, triple lines might arise. For example, a motion represented by

\[ x = a \cos (\xi t + \alpha) \cdot \cos (\eta t + \beta) \cdot \cos \theta t, \]

in which \( \xi, \eta \) and \( \theta \) have nearly equal values, would produce a triple line in association with a single line far separated from it.

It thus appears that even a vibration in a straight line may be such as will produce triple lines. And, of course, more complex motions can generate them under fewer restrictions. But in all cases, if (as is always possible) the motion be resolved into motion in a simpler 'dominant' orbit affected by perturbations, the perturbations, or some of them, must be of large amount, i.e. must have periodic times which are comparable with that of the motion in the 'dominant' orbit. In fact, slow perturbations give rise to close equidistant lines, so that triple lines, other than those that are equally spaced, can arise only in cases where the orbit corresponding to our dominant orbit is not predominant over some of its perturbations.
a full symbolical representation of the resultant motion. If \( e_m \) represents the elliptic partial whose frequency is \( m \), then the resultant motion may be concisely represented by the symbolical equation

\[
\text{Resultant motion} = e_{m_1} \oplus e_{m_2} \oplus e_{m_3} \oplus \&c.,
\]

where the symbol \( \oplus \) signifies "superposed upon." Now, of these several elliptic components, we can obtain from the observations full details, except unfortunately in at least two particulars. There is nothing in the spectrum which can reveal to us the phases in which either they, or the apsidal motions by which they are affected, are at any one instant of time: and these phases are essential to the completeness of the symbolical equation, which when written out in full would appear as follows:

The position of the electron at the instant \( t \)

is identical with

the position of the point \( P \) at that instant in the pendulous elliptic component whose frequency is \( m_1 \)

superposed upon

its position at that instant in the pendulous elliptic component whose frequency is \( m_2 \)

superposed upon,

\&c., \&c., \&c.

There are under the most favourable conditions at all events two unknown constants in each term of the above symbolical equation, and under unfavourable conditions the number of unknown constants may be five—constants to the value of which the appearances in the spectrum give us no clue.

Under these circumstances the best course would appear to be to frame hypotheses as to what the motion of the electron is, and to find whether we can think of any motion which would have elliptic partials with the periodicities, forms, relative amplitudes, and directions of motion which the observations indicate, and which would retain their periodic times through a great range of temperature.

One naturally thinks first of the motion of an electron travelling without friction along a prescribed path under the influence of a central attraction varying directly as the distance. The curve to which it is strammelled being represented by

\[
r = kF(\theta),
\]

the function \( F \) may evidently be such as to produce the observed series of lines; and if the dynamical conditions were such that \( F \) does not alter during the flight of the molecule, \( k \) must diminish when energy is transferred to the surrounding
æther. This represents a state of things under which, though the size of the curve would dwindle during the flight of the molecule, the periodic times would remain unaltered, and the lines in the spectrum unchanged in position. However, though this agrees in many respects with what is observed, the conditions are evidently not so simple, since under these conditions the lines of the spectrum, while fainter at lower temperatures, would retain the same relative intensities at all temperatures, which is not the case.

If the vortex theory of ponderable matter be true, it is in the study of the dynamical, or rather kinematical, relations in, and in the neighbourhood of, vortex rings and tangles, that we must put our hope. The vortex hypothesis, however, would suggest charges of magnetic moment rather than of statical electricity as associated with the atoms of ponderable matter. Perhaps both are present, and that the electrical charges are maintained by motions of the magnetism. Some motion of this kind must apparently be consequent on the velocity of over 30,000 metres per second with which the molecule, in common with the rest of the earth, is travelling through the rectilinear vortices of the æther. We must remember, too, that statical charges of electricity consist of motions or stresses not in the molecules themselves but elsewhere. These considerations naturally suggest others, but we need not follow them up, as it is unnecessary for our present purpose to do so. This is fortunate, since we can as yet only grope in the region which concerns itself with the fundamental facts of nature.

Whatever our ignorance on such subjects may be, one solid advance seems to be harvested by the investigation in the foregoing pages. It has shown how to interpret the spectrum of a gas when, as in the case of the monad elements, it consists of double lines, so as to extract from the observations important particulars about the several pendulous elliptic components of some of the motions going on within the molecules; it indicates the character and the limits of the information about these motions which the spectroscope can supply; and it puts us on the track of further knowledge by guiding the hypotheses that we should frame. It also cannot fail to impress upon us what an amazingly complicated system even one molecule of matter is; what an inconceivable number and variety of events are crowded into every speck of space about us, within even the millionth part of one second of time; and how very little about nature is yet known to man.

In this branch of investigation we are woefully in want of more minutely exact and fuller observations on the spectra of gases than have yet been published. It may be hoped that there will be a great improvement in this respect when the great work is published which has been recently announced by Professor Rowland from the laboratory of the Johns Hopkins University.
But this great work will lose much of its availability for such inquiries as the present, unless it be accompanied by equally exact determinations of the refractive indices of air throughout the spectrum. We cannot even verify Balmer's law without these essential co-efficients.

---

POSTSCRIPT.

A good illustration of the time-relations of the motions that are concerned in the production of spectral lines can be very simply made by screwing a small hook into the middle of the lintel at the top of a doorway, and hanging a heavy bob from it by a piece of silk or pack-thread of such a length that the middle of the bob is 39 inches from the hook—about as long as an ordinary door is wide. The oscillation period of this conical pendulum will be two seconds, the same as that of a pendulum beating seconds.

Place a table in the doorway, and on it some kind of pointer, such as a candle or bottle, supported by a box if necessary to make it reach nearly to the bob.

Now start the bob in a long (approximate) ellipse. We may take this to represent the motion of the electron in a molecule of sodium, as it swiftly revolves in that elliptic partial which produces the great yellow sodium line. The ellipse of our conical pendulum will be seen to have an apsidal motion owing to the resistance of the air. It is in the same direction as the revolution of the bob in the ellipse. This is the right direction to represent the apsidal motion which takes place in the molecule, but it is probably too swift. The apsidal circuit in our apparatus may perhaps be completed in some five or ten minutes, whereas, to correspond with the real event in the gas, it should take $1^h 6^m 8^s$ to get through each revolution. Further, the bob parts with its energy to the surrounding medium far too hastily, and will perhaps come to rest in less than an hour. It should be able to persist in describing its orbit for several months, to be like the electron. There is, however, no difficulty in making allowance for these defects. We should, then, suppose the bob to be given a fresh impulse some eight or nine times every fortnight, to represent on the time-scale that we have chosen the recurrence of the encounters between the molecule and its neighbours, which from time to time revive its internal motions. Finally we are to imagine our pendulum kept going in this way without intermission for thirty-two years; by which time the number of the several representative events in the apparatus will have just accumulated up to being the same as the number of the corresponding actual events that are going on within each molecule of the vapour of sodium in every millionth of a second.
Another observation of general application seems worth making here. Each molecule of gas at atmospheric pressures and temperatures, meets with about 7000 encounters in the millionth of a second, and of course those which fall to the lot of one molecule must happen under a great variety of circumstances. Moreover, immense numbers of these molecules are present, something like a thousand millions* in every cubic micron of air; while in the liquid state they are still more numerous, about a thousand times as many of the gaseous molecules being now crowded into each cubic micron. They are besides now jostled almost without intermission, instead of each encountering its neighbours only at intervals, as in a gas. There are therefore abundant chances for extremely rare circumstances to occur in their struggles with one another, at what we should deem very short intervals of time and space; and it is probable that many important chemical and physiological effects that appear to us to take place with even explosive promptitude, have in reality to wait long (from the molecular standpoint) for their appropriate opportunity to arise.

* See Phil. Mag. for August, 1868, top of page 141. Readers of the Paper here referred to are requested to change the square of 16, at the end of the second paragraph on p. 134, into the square root of 16. The micron in use among microscopists is the thousandth part of a millimetre. About 70 or 80 of the cubic microns would fit into one blood corpuscle.

NOTE ADDED IN PRESS.

Add the following footnote on p. 567:

See Tables, pp. 595–597, and a Diagram, p. 598, of the three series of double lines in the spectrum of one of the light monad elements. The spectrum selected as an example is that of Sodium, and the spectra of the others, viz. Lithium, Potassium, Ruthenium, and Cæsium, are of the same character.
TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1-25.—November, 1877, to September, 1883. (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1-2.—August, 1879, to April, 1882. (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1-14.—September, 1883, to November, 1887. (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.

1. On Fossil-Fish Remains from the Tertiary and Cretaceous-Tertiary Formations of New Zealand. By James W. Davis, f.g.s., f.l.s., &c. Plates I. to VII. (April, 1888.) 4s. 6d.

2. A Monograph of the Marine and Freshwater Ostracoda of the North Atlantic and of North-Western Europe. Section I. Podocopa. By George Stewardson Brady, m.d., f.r.s., f.l.s., and the Rev. Alfred M. Norman, m.a., d.c.l., f.l.s. Plates VIII. to XXIII. (March, 1889.) 12s. 6d.


5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, m.a. (Cantab.), m.r.i.a., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.

6. On the Fossil Fish of the Cretaceous Formations of Scandinavia. By James W. Davis, f.g.s., f.l.s., f.s.a., &c. Plates XXXVIII. to XLVI. (November, 1890.) 7s.

7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleosteanis. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.

8. The Construction of Telescopic Object-Glasses for the International Photographic Survey of the Heavens. By Sir Howard Grubb, m.a.i., f.r.s., Hon. Sec., Royal Dublin Society. (June, 1891.) 1s.


11. On the Cause of Double Lines and of Equidistant Satellites in the Spectra of Gases. By George Johnstone Stoney, m.a., d.sc., f.r.s., Vice-President, Royal Dublin Society. (July, 1891.) 2s.
[November, 1891.]

THE

SCIENTIFIC TRANSATIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

XII.

A REVISION OF THE BRITISH ACTINIAE. PART II.: THE ZOANTHEÆ.
By ALFRED C. HADDON, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and MISS ALICE M. SHACKLETON, B.A. Plates LVIII., LIX., LX.

DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORGATE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.
1891.
XII.

A REVISION OF THE BRITISH ACTINÆ. PART II.: THE ZOANTHEÆ.

By ALFRED C. HADDON, M. A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and MISS ALICE M. SHACKLETON, B.A. PLATES LVIII., LIX., LX.

[Read February 18, 1891.]

CONTENTS.

<table>
<thead>
<tr>
<th>CONTENTS</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>609</td>
</tr>
<tr>
<td>General account of the Anatomy of the Zoanthæ</td>
<td>612</td>
</tr>
<tr>
<td>Classification of the Group</td>
<td>626</td>
</tr>
<tr>
<td>Systematic Account of the British Zoanthæ</td>
<td>634</td>
</tr>
<tr>
<td>Bibliography</td>
<td>663</td>
</tr>
<tr>
<td>Index</td>
<td>671</td>
</tr>
</tbody>
</table>

INTRODUCTION.

The first part of this Revision dealt with a new sub-family of the Sagartidæ, the Chondractinæ, which included the genera Chondractinia, Hormathia, Chitonactis, Actinauge, and Paraphellia. A few notes were made on the genus Sagartia; and details are given of British representatives of Gephyra dohrnii. The British members of the families Edwardsidæ and Halcampidæ were described; and the nature of Gonactinia prolifera was discussed. An account was also given of the arrangement of the mesenteries in the Zoanthæ. The Paper concluded with a summary of the development of the mesenteries of Actinia; and certain general considerations were advanced on the phylogenetic value of the mesenteries. Unavoidable circumstances caused this first part of the Revision to be heterogeneous in character, and unsatisfactory in many details.

The present instalment of the Revision is confined to a very distinct group of the Actiniae. Although there has been considerable confusion within the group, the
Zoanthæ themselves have, since the time of de Blainville, been recognized as a well-marked division of the Actiniae.

With the exception of the genus Sphenopus, and certain free varieties of the genus Epizoanthus, all the members of this group are permanently fixed, and with very few exceptions form colonies, the individuals of which are united by the adhering base or coenenchyme. The coenenchyme extends laterally, and from it new polyps arise, which remain permanently connected with the colony.

The coenenchyme may be band-like or form broad encrusting sheets; usually it is thin, but in the genus Palythoa it is so thick that the polyps are more or less immersed within it. The polyps may be placed at considerable intervals from each other, or they may be crowded together, the latter condition being usually due to gemmation from the base of the polyps rather than from the coenenchyme.

It is characteristic of the group for the body-wall of the polyp and coenenchyme to be incrusted with foreign particles—grains of sand, spicules, foraminifera, and such like. Some genera, such as Palythoa and Sphenopus, are always densely incrusted; the incrustations in Parazoanthus vary according to the species from a considerable amount to very few; finally, the genera Zoanthus and Mammillifera are unincrusted.

The Zoanthæ have the same body-regions as other Actiniae, with the exception of the basal disc, which must necessarily be absent in the colonial forms, and of a physa in the free forms. In all the column is divisible into scapus and capitulum; the former is usually rigid. In nearly all preserved specimens the capitulum is retracted, and this appears to be generally the case when living, for these forms do not fully expand so frequently as most other sea-æmones. The capitulum is usually thrown into triangular ridges.

The tentacles are bicyclic, and may be very short or moderately long. When fully expanded, the oral disc may be flat or projecting. The mouth is always linear. Only one Æosophageal groove is present.

The colours are usually various shades of yellow, buff, and brown, due to the sand incrustations; some have varied colours—pink, green, violet, and so forth—but it is very rare for the colours to be so vivid as is customary among other Actiniae.

Reproduction takes place by means of ova, by basal and coenenchymatous gemmation, and by fission.

The foregoing are all the characters which are available for the field naturalist, and, until quite recently, were the only ones on which the definition of species and their systematic arrangement were based. These purely external characters are more than usually unsatisfactory for diagnostic purposes; hence
the not unnatural confusion into which the group has fallen, and from which it has, to a certain extent, been extricated through the labours of Erdmann and McMurrich. In no group is it more necessary to combine anatomical and microscopical examination with the methods of the older zoologists—for the species of Zoanthæ can only be established after sections have been cut and studied. The identification of new material with recognized species requires the utmost circumspection.

It is impossible to determine the genus to which many previously described species belong until the types have been re-discovered, and then submitted to an anatomical investigation. A complete monograph of the group is at present an impossibility. We have, however, ventured as far as we safely could in this direction.

We have investigated the anatomy of eleven species belonging to five genera of Zoanthæ from Torres Straits, besides several other forms, at the same time that we were occupied upon the British representatives. Our Paper on the Torres Straits specimens is published simultaneously with this one, and in the same Journal; and we would ask those who are interested in this group to study both Papers together, for the two are, to a certain extent, complementary to each other.

Methods.—All the specimens examined by us were preserved in alcohol, and when a sufficient quantity of strong alcohol is used this answers perfectly well. We stained the objects whole in borax carmine, imbedded them in paraffin, and cut them with a "rocking" microtome. In a few cases we stained the sections after they were fixed on the slides.

The unincrusted genera are very easy to cut, and so are some of the incrusted forms, especially some of the species of Parazoanthus. Those wishing to study the anatomy of the group cannot do better than commence with P. axinella, which is very easily cut by the ordinary paraffin method. It was perfectly unnecessary for von Koch to employ his "Schliff-methode" (Morph. Jahrb. vi., 1880, p. 359) when investigating this species. We mention this solely to prevent others from taking superfluous trouble. The different species of the genus Epizoanthus are, as a rule, difficult to sectionize, on account of the incrustations. E. poguriphilus is, however, practically free from them; owing to the great thickness of the mesoglea in this species, celloidin is a better imbedding material than paraffin, as heat has to be employed in the latter method. As a rule, the incrustations in Zoanthæ from coral seas are calcareous, and admit of being readily dissolved away. We use nitric acid for this purpose.

The use which we have made of the Papers of Erdmann and McMurrich will emphasize the indebtedness of students of the Zoanthæ to those investigators. References to other workers will be duly acknowledged where we
utilize their results. The laborious monograph of Andres has been in constant requisition.

It is now our pleasing duty to acknowledge the assistance of many friends. The Rev. Canon. A. M. Norman and Professor W. C. Mc'Intosh have generously placed the whole of their collections at our service; and it is due to the considerable number of foreign (Mediterranean and North Atlantic) specimens belonging to the former that we have been enabled to determine several non-British species. The Director of the Marine Biological Laboratory at Plymouth, and Mr. G. Y. Dixon have also supplied us with specimens, as have also our foreign colleagues, Drs. D. C. Danielssen and J. Playfair McMurrich. Finally, we have to thank Dr. E. Perceval Wright for the loan of books and for ready assistance in the solution of taxonomic and synonymic difficulties.

GENERAL ACCOUNT OF THE ANATOMY OF THE ZOANTHÆ.

The main external characters of the Zoanthæ have already been given in the Introduction; and before giving a detailed account of the anatomy of the group it will be necessary to say a few words as to the anatomy of these Actiniæ.

As in other Actinozoa, the body-wall is composed of three layers: the ectoderm, the mesoglea, and the endoderm. There is now no need to adduce arguments in favour of the employment of the second of these terms.

The mouth leads into a rather short oesophagus or stomatodæum, the walls of which are often thrown into folds; at one end a distinct and sometimes a very deep groove is present, for which one of us has suggested the name of "sulcus," or sulcar groove. Projecting into the cavity, or coelenteron of the polyp, from its body-wall, are a number of soft plates which are known as mesenteries; sometimes these are called "sarcosepta," and occasionally they are erroneously spoken of as "septa." The employment of the latter term cannot be too strongly deprecated as leading to confusion with the septa, or calcareous radial partitions of the Madreporaria.

The mesenteries of the Zoanthæ fall under two categories—

(1) The large mesenteries which extend from the body-wall to the stomatodæum, and which alone bear mesenterial filaments and gonads. These are the "perfect mesenteries" or "macrosepta" of authors.

(2) The small mesenteries which extend only slightly from the body-wall into the coelenteron, and which are sterile, and do not bear mesenterial filaments. These are the "imperfect mesenteries" or "microsepta."

As in most Actiniæ a pair of mesenteries occurs at each end of the oesophagus; these are usually spoken of as the "directives," or "directive mesenteries."
The mesenteries which yield such a valuable aid to classification in the Actiniæ generally are arranged in this group in a very uniform manner.

In the first part of this revision (1889, p. 343), a short account is given of the history of the elucidation of the arrangement of the mesenteries in the Zoanthæ. Since this was written the second part of Hertwig's "Challenger" Report has been published, without, however, adding anything to Erdmann's account. McMurrich has also written two valuable Papers (1889 and 1889 a), but no new type of mesenteric arrangement has been described beyond those first pointed out by Hertwig (1882), and properly described by Erdmann.

It is necessary to have a recognized system of terminology in order to describe the arrangement of the mesenteries in the Actiniæ; and it is advisable to have such a terminology as is applicable to the whole of the Actinozoa. One of us has already (1889) proposed the adoption of certain terms, and the abolition of others which have not a precise meaning—as, for example, such words as "dorsal" and "ventral," these latter were replaced by "sulcular" and "sulcar," respectively. When only one axial cesophageal groove is present, it is usually (?) always) the sulcar. In the same Paper attention was called to the value of the order of the appearance of the mesenteries in young Actiniæ, as suggesting the affinities of different groups of sea-anemones. The following diagram illustrates the proposed method of naming the mesenteries and chambers at a stage when twelve mesenteries have made their appearance:

![Diagram of mesenteries and chambers](image)

**Examples.**—Edwardsia has a pair of sulcular and a pair of sulcar directives; a sulculo-sulcular lateral mesentery, and a sulculo-sulcar lateral mesentery on each side, all of which are perfect.

The larval form of Zoanthus has a pair of sulcular imperfect directives and a pair of sulcar perfect directives; a sulculo-sulcar lateral perfect mesentery, a sulco-sulcar lateral imperfect mesentery, a sulculo-sulcar lateral perfect mesentery, and a sulco-sulcar lateral imperfect mesentery on each side.
The larval form of Epizoanthus agrees with Zoanthus, except that the sulco-sulcar lateral mesenteries are perfect.

In the Zoanthæ new mesenteries appear in the sulcar exocœles in such a way that the mesenteries nearest the sulcus are the youngest, and those furthest from it the eldest.

In the Sagartidæ the new mesenteries appear in pairs in all the exocœles.

The mesenterial filaments, the gonads, the mesenteric canals, and the coenenchyme will be dealt with later on. We will now proceed to describe the structure of the Zoanthæ in greater detail in the following order:—

.Body-wall—ectoderm, incrustations; mesogloea, cell-enclosures, endodermal bays, ectodermal bays; endoderm, diffuse endodermal muscle, sphincter muscle; capitulum.

.Tentacles and Disc.

.Esophagus.

.Mesenteries.—Imperfect mesenteries, perfect mesenteries, reflected ectoderm and mesenterial filaments, mesogloea, canals, endoderm, muscles, gonads.

.Coenenchyme.

.Development.

.Parasites.

.Body-wall.—Ectoderm.—The ectoderm is very liable to be rubbed off in the incrusted genera; where present it generally appears as a continuous layer of narrow columnar cells. In the unincrusted genera, in Gemmaria macmurrichi and in Epizoanthus paguriphilus, the ectoderm is traversed by strands of mesogloea, which unite to form a layer peripheral to the ectoderm, and which, in some species break up the ectoderm into more or less cubical blocks (Pl. lix., fig. 6).

External to the ectoderm there is always a cuticular layer which may be very thin, and stains of a darker colour (Parazoanthus dixoni, Pl. lix., fig. 9), or it may be thick, in which case it rarely stains, and is often impregnated with dirt (Epizoanthus wrightii, Pl. lix., fig. 3).

As the cuticle is an ectodermal secretion in forms with a continuous ectoderm, and, as the peripheral layer of mesogloea must also be of ectodermal origin, and is, as a matter of fact, often indistinguishable from the cuticle, we do not consider it of any importance to discriminate between them in the forms with discontinuous ectoderm.

The above-mentioned layer of mesogloea, peripheral to the ectoderm, is that which is called the subcuticle by Andres (1877, p. 222).

The ectoderm usually contains nematocysts, which M'Murrich and others have failed to observe. As a rule these do not stain readily. In some species they are clear; in others—e. g. E. norvegicus (Pl. lix., fig. 5), where they are, by-the-by,
unusually numerous—they contain pigment granules. In *E. paguriphilus* they are very dark; often they have a yellowish colour, and are somewhat opaque.

Zooxanthellae are present in the ectoderm of the three species of *Isaurus* which have been microscopically examined, and in many other species of the Brachycnemiæ, but apparently not in all. We have not found them in any of the Macrocnemiæ.

**Incrustations.**—The incrustations which form such a characteristic feature of this group of *Actiniae* are absent in the genera Zoanthus and *Isaurus*, though very rarely a stray spicule, or grain of sand, may be entangled in the cuticular layer of these genera.

With regard to the other genera, according to our experience, it appears that certain species have a proclivity for a particular kind of incrustation. The character of the incrustation must be conditioned by the precise habitat, i.e. whether sand-grains are calcareous or siliceous, or, again, whether the bottom is sandy or stony; if sponges are abundant on a rocky bottom (as, for example, in Albany Pass, Torres Straits), the forms will probably largely make use of sponge-spicules, as in *Parazoanthus douglsii*. The best example we have of apparent selection is in the case of *Epizoanthus incrustatus*; of this species we have cut specimens from Norway, Shetland, West of Ireland, and N. E. America (*E. americanus*, Verrill), and in all cases we find the incrustations to be composed almost entirely of grains of sand. In the single specimen we have been able to examine, of *E. macintoshti*, from Shetland, the incrustations are almost entirely Foraminifera. In Norman's type specimens of *Parazoanthus anguicoma*, from Shetland, the incrustations include grains of sand, Foraminifera, and sponge spicules; this holds good for the same species from the West of Ireland, as well as for the other species (*P. dixoni*) from the same district.

The amount of incrustation also varies—for example, the species of *Epizoanthus* are usually thickly incrusted, but in *Epizoanthus paguriphilus* the incrustations are very few in number. In *Parazoanthus dichroicus* there are very numerous incrustations, but in *P. axinellæ* they are sparse, and in *P. dixoni* there are still fewer.

**Mesogloea.**—The mesogloal ground substance is always homogeneous; it is penetrated by numerous minute cells, which are sometimes star-shaped, but more frequently produced at each end into a long fibril which extends in a radial direction. Some of these fibrils are undoubtedly connected with the ectoderm, and others with the endoderm (Pl. Lxiv., fig. 1)*; it is impossible to determine whether some may not stretch right across the mesogloea. We have not been able to satisfy ourselves of their presence in every case (ex. *E. wrightii*).

* Plates xxi. to *xiv. will be found in the Memoir of these Transactions immediately succeeding this one, viz. that on the Zoanthæ of Torres Straits. They are frequently referred to in the present account of the anatomy of the group.
Cell enclosures.—Large ectodermal canals, penetrating the mesogloea, are very characteristic of the genus Zoanthus; they also occur in Parazoanthus. In *Z. coppingeri* there are numerous large anastomosing canals which arise from the ectoderm (Pl. lxii., fig. 1), and have a general radial direction; many of the canals pass into the mesenteries.

In Isaurus the canals are relatively much smaller than in Zoanthus, and are more broken up than in *Z. coppingeri*, and undoubtedly have an endodermal as well as an ectodermal origin (Pl. lxiii., figs. 5 and 6).

The chief feature of the canal system in Parazoanthus is the presence of an encircling sinus, which lies just beneath the endoderm, and extends throughout the whole body-wall. This sinus is not everywhere continuous, but is frequently crossed by bars of mesogloea (Pl. lix., fig. 8). It is connected with the ectoderm by radial, occasionally branched canals. In *P. anguicoma* and *P. dizoni*, and in some other species, very fine canals connect the sinus with the endoderm (Pl. lix., fig. 9). Although the encircling sinus may have connexions with the endoderm, these are very delicate, and the sinus itself is undoubtedly of ectodermal origin. The encircling sinus is the same as the "ring-canal" described by Erdmann in his "sp. 8 Palythoa sp." (1885, p. 469). [This is the *Palythoa anguicoma* of Hertwig, which we believe to be another species, for which we would suggest the name *Parazoanthus hertwigi*.] Nematocysts are present in the canals of many of the species of Zoanthus and Parazoanthus; possibly they are of universal occurrence in the canals.

In *Gemmaria macmurrichi* a somewhat similar encircling sinus is present, but it is very largely broken up by the mesogloea into a number of vertical canals which appear in transverse section as a series of lacunae, each one lying immediately below the union of a mesentery with the body-wall (Pl. lxiii., fig. 7). These vertical canals are often connected by finer ones.

Lacunæ are found in all the genera of the Zoanthæ except Epizoanthus and Sphenopus. In Zoanthus it appears that the canals are more or less broken up to form the lacunæ, least so in *Z. coppingeri* and *Z. danæ* (as identified by Hertwig), and most so in *Z. jukesii* (Pl. lxii., fig. 2), in which species continuous canals are rare; the same also obtains in *Isaurus asymmetricus*. In Palythoa there are no continuous canals; but lacunæ are present, as these are so similar to those which we know to be of ectodermal origin in other species; and as nematocysts are present, we believe that these lacunæ are of ectodermal origin (Pl. lxiii., figs. 8 and 9).

Small groups of cells, irregularly scattered in the mesogloea, are especially characteristic of the genus Epizoanthus; they may be very numerous, as in *E. pagonultiphilus* (Pl. lix., fig. 6), and in some of the species described by Erdmann, but in other species, *E. incrustatus*, *E. couchii*, and *E. wrightii*, they are very rare. They
are abundant in the *Parazoanthus dichroicus*, and are also common in *P. anguicoma*, and *P. douglasi*. They occur also in *Gemmaria macmurrichi*, *Palythoa howesii*, and *P. kochii*.

We have no proof that these small and isolated groups of cells, which have been aptly termed "cell-islets" ("Zellinseln") by Erdmann, are connected in any way with the canals or the lacunæ, and, like that investigator, we do not know their origin. We regard these islets as simply groups of ordinary mesogloa cells.

**Endodermal and ectodermal bays.**—We may here refer to the endodermal bays described for *Isaurus* ["*Mammillifera*"] *tuberculatus* by M'Murrich (1889, p. 118); he says: "In some of my sections deep bays can be seen running from the endoderm into the mesogloa, and from their ends and sides numerous canaliculi can be seen branching out. These bays can be found in various states of enclosure by the mesogloa, the cells which they contain being in some cases continuous with the general endoderm, in other cases almost separated from it, and finally quite so. So, too, with the ectoderm." We have found similar deep endodermal bays in *Isaurus asymmetricus* (Pl. lxiv., fig. 9), but in no case were the bays quite separate from the general endoderm. In our species the ectodermal bays (Pl. lxii., fig. 4) differ considerably from those of M'Murrich's species; the latter we have been able to examine through the courtesy of our friend, and as he has not figured one of these bays we add one for comparison (Pl. lxiii., fig. 3).

**Endoderm.**—The endoderm of the body-wall presents few features worthy of remark. In *I. asymmetricus* we have found nematocysts smaller than those which occur in the ectoderm. Zooxanthellæ are present in the three species of Zoanthus from Torres Straits, and appear to be characteristic of this genus as well as *Isaurus*. They are also extremely numerous in *G. mutuki*, and are present in *Palythoa howesii* and *P. kochii*. In *Parazoanthus dixoni* the endoderm is thickened into ridges between the mesenteries, but in most cases it is of uniform thickness.

**Diffuse endodermal muscle.**—The base of the endoderm forms a feeble but complete muscular sheath; as the fibres run in a horizontal direction, the muscle is scarcely to be seen in transverse sections; in vertical sections (Pl. lxx., figs. 9 and 12) they are readily seen.

**Sphincter muscle.**—The diffuse endodermal muscle of the general body-wall becomes converted in the capitular region into a sphincter muscle, which in contraction causes the introversion of the corona and capitulum. The genus *Parazoanthus* is unique amongst the Zoanthæ in possessing an endodermal sphincter. This fact was first discovered by Erdmann (1885, p. 468), who made this a primary character in the definition of his interpretation of the genus *Palythoa*, of which he took *P. axinellæ* as the type. As we shall subsequently explain, Erdmann's genus *Palythoa* cannot stand; so we have erected the new genus *Parazoanthus* in its
stead. The infoldings of the endodermal sphincter, especially in its upper portion, are frequently so cut across by the razor in sections as to appear isolated, and thus the muscle might be supposed to be partly mesogleal in character (Pl. lxi., fig. 8). It is possible that this may actually occur to a very slight extent. In either case the distinction between Zoanthæs with an endodermal and a mesogleal sphincter is not so fundamental as might appear at first sight.

All other Zoanthæs have a mesogleal sphincter. In Sphenopus the sphincter is extremely long, as Erdmann has previously remarked; Zoanthus alone has a double sphincter (Pl. lxiv., figs. 3 and 5).

Capitulum.—The capitulum, as all authors have described, is thrown into ridges; these have a certain amount of specific value, but too much reliance should not be placed upon this character.

In all species the ectoderm retains its character as a continuous epithelium. In Z. coppingeri the ridges are crowded with nematocysts, but we do not find this of common occurrence.

Tentacles.—The ectoderm of the tentacles contains numerous sausage-shaped nematocysts. The deeper layer of the ectoderm usually exhibits a well-marked nervous layer, the nerve-cells of which are shown in Pl. lxiv., fig. 2. There is a diffuse ectodermal muscular sheath, the fibres of which have a longitudinal direction.

The mesoglea is usually thin. The endoderm is relatively thick; and in Z. coppingeri, Z. jukesii, and Z. macgillivrayi zooxanthellæ are here especially abundant, but in I. asymmetricus and in Palythoa howesii and P. kochii, although they are present in the endoderm of the body-wall, few, if any, are to be found in this region. In Z. coppingeri numerous nematocysts of oval shape, similar to those found in the ectoderm of the body-wall, are present in the endoderm of the tentacles (Pl. lxiv., fig. 2). And in some of our specimens of E. couchii similar nematocysts are to be found in the ectoderm of the tentacles. A diffuse endodermal muscular layer consisting of fibres which run in a circular or horizontal direction, and which may be regarded as an extension of the muscular layer of the body-wall, is found in the tentacles of all our species.

Disc.—The structure of the disc is usually similar to that of the tentacles. As in the latter, there are no incrustations.

Oesophagus.—The ectoderm of the oesophagus is usually more or less folded; but as the degree of folding is variable in different individuals of the same species, and probably also in the same individual in different conditions of contraction, this character is of little value for systematic purposes. The same may be said of the nature and extent of the groove. A sulcal groove is always present, but it is scarcely discernible in our specimens of I. asymmetricus, and in one of the specimens of E. incrustatus (Pl. lx., fig. 1). In other specimens of the latter species it is,
however, distinct. Nematocysts are found in the ectoderm of the oesophagus of Palythoa caesia (?), E. couchii, and E. arenacea.

The mesogloea of the oesophagus is generally thin, but in many species of Epizoanthus and of Parazoanthus it is much thickened in the groove. Cell enclosures are generally absent in this region, but we have seen a few cell-islets in the mesogloea of the groove of P. anguicoma (one specimen), and they are also present in that of P. dichroicus.

Mesenteries.—The mesenteries which are such a valuable aid to classification of the Actiniæ generally are arranged in this group in a very uniform manner, which we have already described.

Imperfect mesenteries.—The imperfect mesenteries vary in the extent to which they project into the coelenteron. In E. incrustatus, and in Parazoanthus douglasii they are very small, whereas in P. dizoni they are well developed. When canals are present in the perfect mesenteries they are also to be found in the imperfect.

Perfect mesenteries.—There is no distinction between any of the perfect mesenteries.

Ectoderm.—The presence of ectoderm in certain mesenteries of the Anthozoa appears to be now fairly well established. E. B. Wilson ("Mesenterial Filaments of the Alcyonaria"); Mitth. Zool. Stat. Neapel, v. 1884) came to the conclusion that the "dorsal" pair of filaments in the Alcyonaria were ectodermal in origin, but that the other six filaments were solely endodermal; these two kinds of filaments can be readily distinguished histologically. Some years previously von Heider (Cerianthus membranaceus, Haime: Sitz. kais. Acad. Wien, Ixxx. 1879) believed, solely from a histological study of the adult Cerianthus, that the filaments of that form were ectodermal. The Brothers Hertwig (Die Actinien, 1879) pointed out that embryological deductions based on adult histology were not very reliable, and also brought forward, as an objection to von Heider's view, the existence of filaments on imperfect mesenteries in the Actiniæ generally. H. V. Wilson (Journ. Morph. ii., 1888) has shown for the coral Manicina, and J. P. M'Murrich (ibid. iv. 1891) for the Actinian, Rhodactis, that the mesenterial filaments are derived from the ectoderm of the oesophagus.

From the histological characters and absolute continuity of what we have termed the "reflected ectoderm" of the mesenteries with the ectoderm of the oesophagus on the one hand, and with the mesenterial filament (craspedum) on the other, we have no doubt as to the morphological identity of these tissues.

Reflected Ectoderm and Filaments.—The mesenteric ectoderm consists of two portions, an upper, which we speak of as the "reflected ectoderm," and a lower portion, which runs down the edge of the mesentery, and is known as the mesenterial filament, or "craspedum" of Gosse. These two are perfectly continuous with each other and with the ectoderm of the oesophagus.
In looking at a side view of a mesentery such as that of Z. macgillivrayi (Pl. lxiv., fig. 5) it will be seen that the ectoderm of the oesophagus passes continuously on to the mesentery where it suddenly becomes greatly thickened, and is thrown into transverse folds; the whole thickening has a crescentic form, first coming upwards and then downwards losing itself in the mesenterial filament. The ectoderm is reflected on both sides of every one of the perfect mesenteries (Pl. lx., fig. 6), and presents a very characteristic appearance in transverse sections (Pl. lxiv., figs. 4 and 6). The folds often present a pinnate appearance, but they are rarely accurately symmetrical on each side.

In some species the endoderm is implicated in the upward reflection of the lower edge of the oesophagus; this is especially noticeable in Parazoanthus axinellae (Pl. lx., fig. 6), but it is not a feature of any morphological importance.

As above mentioned the reflected ectoderm passes gradually into the mesenterial filament. The characteristic trefoil (P. axinellae) (Pl. lx., fig. 6) or V-shape (Z. macgillivrayi) (Pl. lxiv., fig. 7) of the latter in transverse sections is continuous with the peripheral pair of folds of the reflected ectoderm.

The lateral elements of the upper portion of the craspedum gradually become shorter, so that eventually only the median portion is left (Pl. lx., fig. 7). This transition takes place very shortly below the lower level of the oesophagus.

Nematocysts are numerous in the simple lower portion of the mesenterial filament; but they are not readily seen in the upper portion, and we have not observed any in the reflected ectoderm. Unicellular glands and pigment granules also occur in the filament.

The length of the craspeda varies even in the same genus, it apparently being dependent upon the height of the polyp; for example in Z. jukesii, which is a short species, the filaments extend nearly down to the commencement of the coenenchyme, whereas in Z. macgillivrayi they cease about half way down the polyp.

*Mesogloea.*—The mesogloea of the mesenteries exhibits a certain amount of variation in thickness; for example, in the oesophageal region of Parazoanthus dixoni (Pl. lx., fig. 9), the mesogloea is relatively thick, whereas in Epizoanthus paguriphilus (Pl. lx., fig. 5) it is quite thin.

*Canals.*—In describing the canals in the mesogloea of the body-wall, we have already alluded to the fact that in the three species of the genus Zoanthus from Torres Straits which we have examined, they not only arise from the ectoderm, but pass into the mesenteries.

Hertwig (1882, p. 115) describes in Z. danae (?) (cf. 1888, p. 36) a basal "septal canal" "in the supporting lamella of the septa in immediate proximity to the wall." He "never could make out any connexion between this septal canal and the ectodermal cords [i.e. canal system] of the wall"; and he is
“inclined to believe that it is produced from the endoderm.” His reason is that the zooxanthellae, which are found in the mesenteric canal of this species, “force their way into the septal canal, but never into the canals of the wall.” According to our experience there are no connexions between the canal-system of the body-wall and the mesenteric canals in the oesophageal region of the body, although they are numerous lower down. The section Hertwig figures is from the oesophageal region.

M’Murrich (1889 A, p. 64) finds in Z. sociatus, in “one mesentery, the basal canal communicating with one of the spaces in the mesogloea of the column wall.” He adds: “It seems open to question whether the cells of the larger cavities in the mesogloea are not in reality endodermal in their origin.” In his subsequently written, but previously published Paper (1889, p. 114), in alluding to the body-wall canals of Z. flos-marinus, he refers the reader to his description of Isaurus [“Mammillifera”] tuberculatus for his views as to the origin of these canals, evidently believing that the “endodermal bays” of the latter species give rise to some of the canals, the remainder being similarly derived from the ectodermal bays, and then not unnaturally concludes that the mesenteric canals are connected only with the endodermal “spaces” of the body-wall. We have corroborated M’Murrich’s observation as to the double origin of the canal-system in the body-wall of Isaurus; but we have no reason for supposing that the canals in the mesenteries are without exception of endodermal origin, although some undoubtedly are (Pl. lxiii., fig. 5). Our experience leads us to the conclusion that it is necessary to be cautious in arguing as to the origin of these canals from one genus to another. For confirmation of our view, that the mesenteric canals of Zoanthus are of ectodermal origin, we point to the demonstration of this fact for Z. coppingeri (Pl. lxii., fig. 1).

In Z. coppingeri the canals form at the base of each mesentery a large sinus, which extends up the mesentery, nearly to the generative region, where it rapidly narrows, and extends right up the mesentery as the “basal canal.” In Z. jukesii and in Z. macgillivrayi the mesenteric canals are present, though not forming extensive sinuses (Pl. lxii., fig. 2).

In I. asymmetricus the canal system appears in sections as if broken up into lacunæ; but it may really form a continuous system of anastomosing canals.

In Gemmaria rusei (1889, p. 125) and G. isolata (1889 A, p. 66) the mesenteric canal, according to M’Murrich, has the character of a basal canal. We find the same in our two species. Sinuses, extending throughout the whole length of the mesenteries, occur in the three species of Palythoa we have examined. So far as our experience goes canals are absent from the mesenteries of Epizoanthus, and the same obtains for all the species of Parazoanthus except P. anguiicoma and P. dixoni, in which species we have found sinuses in the bases of the mesenteries which have a slight vertical extension.
In Parazoanthus dichroicus cell-islets occur in the mesogloea of the mesenteries, and also in E. paguriphilus.

Nematocysts are sometimes present in the canals and sinuses of the mesenteries (e.g. Z. coppingeri (Pl. lx.1. fig. 1) and Palythoa kowesii); but zooxanthellae are rarely present. We have found them in Palythoa kochii.

Endoderm.—The endoderm of the proximal portion of the mesenteries usually resembles that of the body-wall, except that it more frequently contains nematocysts, as in Z. coppingeri, Z. macgillivrayi, and I. asymmetricus. In the latter species they are much smaller than those of the ectoderm of the body-wall. Zooxanthellae occur in the endoderm of the mesenteries in those species in which they are present in the general endoderm.

McMurrich has carefully described the swollen distal portion of the endoderm of the mesenteries of Z. flos-marina (1889, p. 115, Pl. vii., fig. 4) in that region of the body where the mesenterial filament is simple. We have found a similar enlargement in Z. macgillivrayi (Pl. lxiv., fig. 8), in which nematocysts are present. Our specimen differs from his chiefly in the possession of zooxanthellae and nematocysts; we have not observed in our species that these endodermal cells are "loaded with green granules, closely packed together."

A similar swelling occurs, to a variable extent, in other species; for example, in P. axinella (Pl. ix., fig. 7) it is only moderately developed, and we have not observed nematocysts or zooxanthellae; but these appear to be absent in the general endoderm of this species. Sometimes the swelling is absent, as in E. incrustatus.

We, too, have found, with McMurrich, "foreign bodies of organic nature imbedded in the cells, sometimes being surrounded by a number of cells containing no granules, or occasionally imbedded in the mesogloea" (1889, p. 116). He suggests that these are concerned with digestion (Pl. lxiv., fig. 8).

Muscles.—The muscles of the mesenteries are endodermal and diffuse. As in other Actiniaæ there are two kinds of muscles, the longitudinal and the parieto-basilar.

The longitudinal muscle is often very difficult to distinguish in transverse section, being feebly developed, and forming a simple layer of fibres (Pl. lxiv., fig. 8). In I. asymmetricus and E. paguriphilus, Parazoanthus dixoni, and others, the muscle is better developed, and is slightly plaited (Pl. ix., fig. 9).

The parieto-basilar muscle is usually relatively broader, and extends higher up the mesenteries than in other Actiniaæ; but in Parazoanthus anguicoma and P. dixoni, this muscle is very feebly developed, and only occurs at the insertion of the mesenteries (Pl. ix., fig. 9).

It has been recognized by other investigators that judging by the arrangement of the muscles the mesenteries of the Zoanthæ are paired, although the
HADDON AND SHACKLETON—A Revision of the British Actiniae. 623
two elements of each pair are respectively a perfect and imperfect mesentery, and are independently developed. Recently, however, Danielssen (1889) has thrown doubt upon this paired arrangement, since he finds in the various species he has examined that the muscles are equally developed on both sides of the perfect mesenteries. Owing to the kindness of our Norwegian colleague we have been enabled to examine some specimens of Epizoanthus ["Mardæll"] erdmanni, and our sections show this paired arrangement quite clearly.

Gonads.—There appears to be a general impression that all the Zoanthæ are hermaphrodite. This is certainly not the case in four genera; of one genus we have no facts either way, and in the the remaining two genera the sexes may be distinct or united. Generative organs often appear to be absent in specimens of Zoanthæ, but we have been somewhat fortunate in finding them in those we have examined. Their mode of occurrence will be seen on reference to the Plates in this and in the Memoir on the Zoanthæ from Torres Straits.

Erdmann found that the two species of Zoanthus which he examined ("1 sp. Zoanthus sp. ?," p. 438 (= Z. danæ [?], Hertwig); and "2 sp. Z. sp. ?," p. 447) were hermaphrodite, so he concluded that this was a generic character. M'Currich found no generative organs in the two species he examined. Of the three species we have examined, two specimens of Z. coppingeri were male and three were female; two specimens of Z. jukesii were female, and of the four specimens of Z. macgillivrayi we sectioned none were fertile. The conclusion we arrive at is that the genus is as often dioecious as monoeccious.

M'Currich found that Isaurus ["Mammillifera"] tuberculatus was hermaphrodite, and owing to his courtesy we have been enabled to verify this fact. We have cut several specimens of our I. asymmetricus, but in only one of them could we discover generative organs, and in this case they were feebly developed ova. We cannot, however, assume that the genus is hermaphrodite because one species is undoubtedly monoeccious.

All the remaining genera, so far as is known, are dioecious, except Sphenopus, the gonads of which are unknown.

Neither Erdmann nor M'Currich found generative organs in the five species of Palythoa ("Corticifera") examined by them. We have been more fortunate, since in P. kochii we found male organs alone, and in P. howesii we found only female.

According to our experience all the members of a single colony of dioecious Zoanthæ belong to the same sex; but we cannot lay down any general rule on this point.

Coenenchyme.—The structure of the coenenchyme is similar in every respect to that of the polyps. The only difference consists in the presence of coelenteric canals, which are merely prolongations of the coelenteron of the polyps.
The coenenchyme may occur as stolons, more or less riband-like, or as flattened expansions, or, as in Palythoa, it may fill up the intervals between the polyps. Some zoologists have laid stress on the systematic value of the habit of growth of the coenenchyme; but, as a matter of fact, we have often found that in the same species it varies according to the surface to which the colony is attached, and therefore cannot lay great stress on this character. The genus Gemmaria, as defined by M^Murrich, precisely resembles Palythoa (his Corticifera), with the exception of the character of the coenenchyme, it being absent or lamellar in the former. We consider this a legitimate use of the character of the coenenchyme for taxonomic purposes.

The most interesting varieties of coenenchyme occur amongst those species of Epizoanthus which incrust Gasteropod shells inhabited by hermit crabs. In these cases the coenenchyme dissolves the lime of the shells, which it replaces by its own substance; and thus the carcinæcum practically forms an isomorph of the shell. The spire of the shell is the last portion to be absorbed. In describing the manner in which the polyps are arranged on the coenenchyme, we employ the terms "dorsal," "ventral," "anterior," "posterior," "right," and "left;" these have reference solely to the position of the carcinæcum with regard to the crab when walking.

Development.—We have no account of the development of any Zoanthan, with the possible exception of an observation by Van Beneden (1890), who describes the anatomy of a larval Actinozoon allied to Semper's larva (Zeitschr. f. wiss Zool., xvii. 1867). He regards it as a larva of a "microtypal" (brachychenemic) Zoanthan, on account of the arrangement of the mesenteries. He adds: "What further confirms our opinion, that our larva and that of Semper may be connected with the development of the Zoanthan, is that the constitution of the mesenchymatous lamella is particularly well developed, and provided with numerous cellular elements, of which some have an endodermic origin, the others being derived from the ectoderm" (p. 95). The senior author has very recently (Proc. Roy. Dub. Soc. (N. S.), vol. vii., pt. iii., p. 127, 1891) published a small Paper on a larval stage of the coral Euphyllia, which presents many of the anatomical peculiarities which characterise Van Beneden's larva; it is only fair to add that in the newly-hatched larva of Euphyllia the mesogleæ is thin and without cell-enclosures.*

Parasites.—Some of our specimens of Parazoanthus douglasi from Albany Pass are infested by a Copepod which deposits its egg-capsule in the coelenteron or

* Since the above was in type we have received, through the courtesy of the author, a valuable Paper on "The Phylegeny of the Actinozoa," by Professor M^Murrich (1891), in which he gives an account, and four figures (Pl. ix., figs. 5–8), of two stages in the development of a brachychenemic Zoanthan. We regret we can do no more than draw attention to this Paper.
coelenteric canals of the Zoanthean. The capsules are paired, and contain a large number of ova. We have these in the nauplius stage, and in other stages of development. We have two specimens of the Copepod, but are unable to say whether these are adult or not. The capsules form distinct swellings (Pl. lxI., figs. 19–22) of the body-wall of the Actinian. This fact leads us to suppose that the Copepod remains within the coelenteric cavities while the capsule is developing; and when the latter is ripe it breaks away from it.

We have sections of a Crustacean in the coelenteron of the only specimen of Epizoanthus macintoshi (from Shetland) we were able to cut, but we cannot say anything more about it.

Small, oval, deeply pigmented bodies occur in many parts of the body in Parazoanthus dichroicus and in P. douglasii (Pl. lxII., figs. 5 and 6). They are evidently parasites, but we have been unable to determine their nature.

Problematical rounded bodies, which stain deeply and uniformly with carmine, are present in Z. macgillivrayi, Palythoa howesii, and other species.
CLASSIFICATION OF THE GROUP.

ZOANTHEÆ.

Actiniae 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 occur 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 (Brachycnemineæ), or the second pair may be composed of two perfect mesenteries (Macrocnemineæ). 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 exocoele on each side of the sulcar directives, in such a manner that the sulcar 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 mesogloea 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. BRACHYCNEMINEÆ, n. s.-f.*

Zoanthæ in which the sulcar element of the primitive sulco-lateral pair of mesenteries (cnemes) is imperfect:

GENERA AND TYPE SPECIES.

Zoanthus, Lamarck. Type Z. sociatus (Ellis).
Isaurus, Gray. „ I. tuberculatus, Gray.
 (? Mammillifera, Lesueur. „ M. auricula, Lesueur.)
Palythoa, Lamouroux. „ P. mammillosa (Ellis and Sol.).
Sphenopus, Steenstrup. „ S. marsupialis, Steenstr.

* βραχύς, short; μακρός, long; κύριόν, a radius or spoke of a wheel. We have tried hard to discover a short term for a mesentery, which would readily lend itself to combination with other words, but without
Sub-family. Macrocneiminæ, n. s.-f.*

Zoaanthæ in which the sulcar element of the primitive sulco-lateral pair of mesenteries (enemes) is perfect:—

**GENERAE AND TYPE SPECIES.**

*Epizoanthus*, Gray.  
*Parazoanthus*, n. g.  
Type *E. incrustatus* (Düb. and Kor.).  
,, *P. axinellæ* (Schmidt).

The Zoaanthæ constitute a very well-marked division of the Actiniæ; no connecting forms between these and any other group are known.

The classification of the Zoaanthæ proposed by Erdmann has been adopted by all subsequent writers; and as his was the first which was based on internal anatomy, we need not enter into a discussion of the earlier systems.

Erdmann adopts Andres' two families, the Zoaanthidæ and the Sphenopidæ, with the following definitions:—"Zoaanthidæ: Zoaantheen, welche durch ein Cœnenchym zu Colonien vereinigt werden;" and "Sphenopidæ: Einzellebende Zoaantheen, welche mit ihren abgerundeten Körperende im Sande stecken oder mit einer Art Haftscheibe am Boden festsitzen." It is strange that these families should be based solely upon the habit of growth. In the second family he places Sphenopus and his "genus novum"; the latter is undoubtedly the free (or Sidisia) variety of an Epizoanthus. It is very probable that this is really the free-variety of the type species of Epizoanthus (*E. incrustatus*). As this form passes out of the family we see no reason for retaining a family for Sphenopus, especially as an isolated mode of growth occurs in the other family, as McMurrich has shown that *Gemmaria rusei* is "solitary, being attached to pebbles without the development of any cœnenchyme" (1889, p. 124), and the individuals of his *G. isolata* "were scattered and buried up to the tentacles in the sand" (1889 A, p. 65); and it is characteristic of the genus Isaurus for the polyps to be either solitary, or in small groups with a feeble cœnenchyme. We therefore think it preferable to base divisional characters on anatomical differences.

McMurrich has adopted Andres' three divisions, the third being the Bergidæ. As nothing is known about the structure of the latter we think it better to omit them altogether.

success. The objection to the word "eneme" is that it has reference to the appearance of a transverse section of an Actiniæ rather than to a mesentery as it actually exists. As the investigation of the Zoaanthæ, at least, must principally be made by means of transverse sections, this objection has not much weight.

We acknowledge only one family in the group which we divide into two sub-families, the Brachycneminae, and the Macrocneminae, which are based upon the two well-known types of mesenterial arrangement. It is worthy of notice that, so far as our knowledge at present extends, the Macrocneminae alone are represented in the North Atlantic, although they are world-wide in distribution.

The following Table shows the chief generic distinctions at a glance, and demonstrates that the group is a very homogeneous one. We regard Parazoanthus as being the least specialised genus on account of its having a single endodermal sphincter muscle, and Zoanthus as the most specialised, as it possesses a double mesogloéal sphincter muscle. We omit Mammillifera, as the type species have never been described from an anatomical point of view:

<table>
<thead>
<tr>
<th>Genus</th>
<th>Mesenterial arrangement</th>
<th>Sphincter</th>
<th>Gonads</th>
<th>Body-wall and Connective.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zoanthus</td>
<td>Brachycnemic</td>
<td>Double mesogloéal</td>
<td>(\varphi) or (\varphi), (\varphi)</td>
<td>Unicrusted; well-developed ectodermal canal system.</td>
</tr>
<tr>
<td>Isaurus</td>
<td>Brachycnemic</td>
<td>Single mesogloéal</td>
<td>(\varphi) or (\varphi), (\varphi)</td>
<td>Unicrusted; ectodermal and endodermal bays and small canals; sometimes solitary.</td>
</tr>
<tr>
<td>Gemmária</td>
<td>Brachycnemic</td>
<td>Single mesogloéal</td>
<td>(\varphi), (\varphi)</td>
<td>Incrusted; lacunae; often solitary, always attached.</td>
</tr>
<tr>
<td>Palythia</td>
<td>Brachycnemic</td>
<td>Single mesogloéal</td>
<td>(\varphi), (\varphi)</td>
<td>Similar to above, but polyps immersed in expanded connective.</td>
</tr>
<tr>
<td>Sphenopus</td>
<td>Brachycnemic</td>
<td>Single mesogloéal</td>
<td>(\varphi)</td>
<td>Incrusted; cell-islets; always solitary and free.</td>
</tr>
<tr>
<td>Epizoanthus</td>
<td>Macrocnemic</td>
<td>Single mesogloéal</td>
<td>(\varphi), (\varphi)</td>
<td>Incrusted; cell-islets.</td>
</tr>
<tr>
<td>Parazoanthus</td>
<td>Macrocnemic</td>
<td>Endodermal</td>
<td>(\varphi), (\varphi)</td>
<td>Incrusted; ectodermal canals; cell-islets; encircling sinus; ectoderm always continuous.</td>
</tr>
</tbody>
</table>
In the following list we have enumerated immediately after the generic description all the species which can be definitely referred to any species, adding in brackets [ ] the initials of the zoologists who have investigated those forms, and on whose authority the generic allocations are made. The initials are as follows:—A., Andres; E., Erdmann; E. & H., Erdmann and Hertwig, for those species described in the Supplement to Hertwig’s “Challenger” Report, 1888, the anatomical work on the Zoaanthese being done by Erdmann; H., Hertwig (1882); H. & S., Haddon and Shackleton; M., McMurrough. Although other zoologists have made anatomical investigations on some forms, yet in no other case is there sufficient information given to enable one to determine the generic position of a particular species.

In a few instances we have added those species which we think may safely be regarded as probably belonging to a particular genus, e.g. Palythoa and those species of Epizoanthus which form carcinæa, owing to their having a similar habit of growth to species whose genus is known. Beyond this we have not dared to go, as enough confusion has been made in the group without our gratuitously adding to it.

Family. ZOANTHIDÆ.

Sub-family. BRACHYCNEMINÆ.

ZOANTHUS, Lamarck, 1801.

Brachycnemic Zoaanthese, with a double mesogloal sphincter muscle. The body-wall is unincrusted; the ectoderm is usually discontinuous; well-developed ectodermal canal system in the mesogloæa. Monœcious or dioœcious. Polyps connected by thin coenenchyme.

RECOGNIZED SPECIES.

Z. sociatus (Ellis), 1767.—Dominica, Barbadoes, Guadeloupe, Bahamas, [M.].
Z. flos-marinus, Duch. & Mich., 1860.—St. Thomas, Bermudas, [M.].
Z. danæ (?), of Hertw., 1888.—Bermudas (? if the same as Z. danæ, Le Conte, 1851, Panama), [E. & H.].
Z. confertus, of Hertw., 1888.—Cape of Good Hope (? if the same as M. conferta, Verrill, 1868, San Salvador, Acapulco), [E. & H.].
Z. coppingeri, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].
Z. jukesii, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].
Z. macgillivrayi, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].
Z. sp. (?), Hertw., 1882.—Bermudas, [H.].
ISAURUS, Gray, 1828.

Large brachyeneric Zoanthææ, with a single mesogloæal sphincter muscle. The body-wall is unincrusted; the ectoderm is discontinuous; ectodermal and endodermal bays and small canals in the mesogloæa. Monœcious or dioœcious. Polyps in small clusters or solitary.

RECOGNIZED SPECIES.

*I. tuberculatus*, Gray, 1828.—Guadeloupe, Bermudas, [M.].
*I. spongiosus* (Andres), 1877.—Port Natal, [A.].
*I. asymmetricus*, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].

PROBABLY BELONGING TO THIS GENUS.

*I. cliftoni* (Gray), 1867.—W. Australia.

[M. mammillifera,* Lesueur, 1817.
*M. auricula*, Lesueur, 1817.—St. Vincent; Dominica.
*M. nymphæa*, Lesueur, 1817.—St. Christopher.]

GEMMARIA, Duchassaing et Michelotti, 1860.

Solitary brachyeneric Zoanthææ, with a single sphincter mesogloæal muscle. The body-wall is incrusted with particles of sand. The ectoderm is usually discontinuous, but may be continuous. Lacunæ and cell-islets are found in the mesogloæa. Dioœcious.

RECOGNIZED SPECIES.

*G. rusei*, Duch. & Mich., 1860.—St. Thomas, Bermudas, [M.].
*G. isolata*, M’Murr., 1889.—Bahamas, [M.].
*G. macmurrichi*, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].
*G. mutuki*, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].

PROBABLY BELONGING TO THIS GENUS.

*G. philippinensis* (Gray), 1867.—Philippines.

* The position of this genus cannot be settled until the type species have been recovered and sectionized.
Palythoa, Lamouroux, 1816.

Brachypneumatic Zoanthææ, with a single mesogleal sphincter muscle. The body-wall is incrusted; the mesogloea contains numerous lacunæ, and occasionally canals. Dioecious. Polyps immersed in a thick eoonenchyme.

Recognized Species.

P. mammillosa (Ellis & Sol.), 1786.—Jamaica, = Corticifera lutea of Hertwig, 1888.—Bermudas, probably not C. lutea, Quoy & Gaim., 1833.—Tongatabou, [E. & H.].

P. ocellata (Ellis & Sol.), 1786.—Dominica, Jamaica, [M.].

P. glareola (Lesueur), 1817.—Guadeloupe, Bermudas, [M.].

P. flava (Lesueur), 1817.—St. Thomas, Bahamas, [M.].

P. tuberculosa, of Hertwig, 1888.—Cape of Good Hope; probably not P. tuberculosa, Klunz., 1877.—Red Sea, [E. & H.].

P. howesii, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].

P. kochii, Hadd. & Shackl., 1891.—Torres Straits, [H. & S.].

P. caesia?, Dana (fide H. & S., 1891).—Torres Straits, [H. & S.].

The Following Probably Belong to This Genus:—

P. aggregata (Lesson.), 1830.—Society Archipelago.

P. lutea (Quoy & Gaim.), 1833.—Tongatabou.

P. flavo-viridis, Ehr., 1834.—Red Sea.

P. argus, Ehr., 1834.—Red Sea.

P. caesia, Dana, 1846.—Fiji.


P. caribæorum, Duch. & Mich., 1866.—St. Thomas.

P. cinerea, Duch. & Mich., 1866.—St. Thomas.


P. calcûria, Müll., 1883.
SPHENOPUS, Steenstrup, 1856.

Free solitary brachycnemic Zoanthæ, with a single, very long mesogloëal sphincter muscle. The body-wall is incrusted. Cell-islets are present in the mesogloëa.

RECOGNIZED SPECIES.

*S. marsupialis*, Steenstr., 1856.—Tranquebar, Pulo Faya, China Seas, Gray; (? Madras, H. & S.), [H. & S.].
*S. marsupialis*, var. *bursiformis*, Gray, 1867.—Massachusetts Bay, N. America. (This requires confirmation.)
*S. arenaceus*, Hertw., 1882.—Cape York, [H.].
*S. pedunculatus*, Hertw., 1888.—Philippine Islands, [E. & H.].

Sub-family. **MACROCNEMINÆ.**

EPIZOANTHUS, Gray, 1867.

Macrocnemic Zoanthæ, with a single mesogloëal sphincter muscle. The body-wall is incrusted. The ectoderm is usually continuous, but may be discontinuous; cell-islets in the mesogloëa. Dioecious polyps, connected by coenenchyme, which may be band-like, incrusting, or greatly reduced, as in the free forms.

RECOGNIZED SPECIES.

*E. incrustatus* (Düb. & Kor.), 1847.—Norway, [H. & S.], = *E. papillosus* (Johnst.), 1842.—W. coast of Britain, [H. & S.], = *Sidisia barleci*, Gray, 1858 (free variety).—Shetlands, [H. & S.], = *E. americanus*, Verr., 1864 (and free variety).—E. coast of N. America, [H. & S.], = *E. cancrisocicus* of Hertw. (not of Studer), 1888.—Nova Scotia, [E. & H.].
*E. arenaceus* (D. Ch.), 1836.—Mediterranean, [H. & S.].
*E. couchii* (Johnst.), 1838.—S. W. Britain, [H. & S.].
*E. norvegicus* (Kor. & Dan.), 1877.—Norway, [H. & S.].
E. paguriphilus, Verr., 1882.—E. coast of N. America; W. coast of France; W. coast of Ireland, [H. & S.];
E. parasiticus, of Hertw., 1882.—Japan (probably not of Verrill, 1862), [H.];
E. thalamophilus, Hertw., 1888.—Valparaiso, [E. & H.];
E. stellaris, Hertw., 1888.—Philippines, [E. & H.];
E. elongatus, Hertw., 1888.—Monte Video, [E. & H.];
E. erdmanni (Dan.), 1890.—N. coast of Norway; Spitzbergen, [H. & S.];
E. macintioshi, n. sp.—Shetlands, [H. & S.];
E. wrightii, n. sp.—Dublin Bay, [H. & S.].

PROBABLY BELONGING TO THIS SPECIES.

E. cancrisocius (Martens), 1875, ? of Studer, 1878.—Japan.
E. parasiticus, Verr., 1864.—E. coast of N. America.
E. abyssorum, Verr., 1885.—E. coast of N. America.
E. eupaguri (Mar.), 1882.

PARAZOANTHUS, n. g.

Macronemnic Zoantheæ with a diffuse endodermal sphincter muscle. The body-wall is incrusted; the ectoderm is always continuous; the mesogloea contains ectodermal canals, cell-islets, and an encircling sinus. Dioecious.

RECOGNIZED SPECIES.

P. axinellae (Schmidt), 1862.—Mediterranean, [E.], [H. & S.];
P. anquicoma (Norm.), 1868.—Shetlands; W. Britain, [H. & S.];
P. dixoni, n. sp.—W. of Ireland, [H. & S.];
P. dichroicus, H. & S. 1891.—Torres Straits, [H. & S.];
P. douglasi, H. & S., 1891.—Torres Straits, [H. & S.];
P. (sp.)? (Hertw.), 1888.—Tristan d'Acunha, [E. & H.];
P. hertwigi, n. n.—Tristan d'Acunha, [E. & H.], name proposed by us (see p. 616) for P. anquicoma, of Hertwig, 1888.
SYSTEMATIC ACCOUNT OF THE BRITISH ZOANTHEÆ.

ZOANTHIDÆ.

I. BRACHYCNEMINÆ. (None British.)

II. MACROCNEMINÆ.

EPIZOANTHUS, Gray, 1867.

Spongia (pars), Johnston, 1834.
Dysidea? (pars), Johnston, 1842.
Mammillifera (pars), Auct.
Zoanthus (pars), Auct.

Sidisia, Gray, 1858.
Carolia, Gray, 1867.
Polythoa (pars), Andres, 1884.
Polythoa (pars), Carus, 1884.

Macrocnemic Zoanthus, with a single mesogleal sphincter muscle. The body-wall is incrusted; the ectoderm is usually continuous, but may be discontinuous; cell-islets in the mesogloea. Dioecious. Polyps connected by coenenchyme, which may be band-like, incrusting, or greatly reduced as in the free forms.

The genus Epizoanthus was established by Gray in 1867 for incrusted Zoanthæ: "II. coral attached; cells arising from a foliaceous expanded base. . . . The base expanded foliaceous (parasitic on shells); the cells cylindrical, simple; separate from each other from the base; tentacles numerous" (p. 237). E. papillosus, Johnst., is his type. Verrill adopted Gray's genus. At first Hertwig (1882) agreed with Verrill in using this term to denote incrusted forms which rose above their coenenchyme. After Erdmann's investigations, he (1888) restricted the genus to macrocnemic Zoanthæ, with "Integument incrusted, coenenchyme (mostly?) lamellar; sphincter simple, mesogleal; mesenteries arranged on the macrotype; colonies (mainly?) parasitic" (p. 37). We have studied the type species of this genus, and find that it does conform to Erdmann's and Hertwig's definition of the genus. We may add that all observers have agreed in relegating to this genus all those incrusted Zoanthæ which form carcinaeæia.

In 1858 Gray erected the genus Sidisia for free Zoanthæ, "which may be characterized by the emission of buds on the surface of the cylindrical body" (p. 532), S. barleei being the sole species. He considered that this species "evidently belongs to quite a different group" from Dysidea papillosa, Johnst., which Mr. Barlee (in litt.) informed Gray "was a Zoanthus, allied to the genus Mammillifera of Lesueur," an opinion which Gray adopted.

Our investigations prove that S. barleei is only a variety of E. incrustatus (= E. papillosus). We do not propose to keep the name Sidisia for the genus, although it has priority, and for this reason: it was solely erected for a species which is only
a variety of an older form; and the name has only been occasionally retained for this variety of that particular species, whilst Epizoanthus has been universally adopted for the more typical forms of this genus. Both names were originated by Gray, and we have therefore less hesitation in keeping to the latter.

Erdmann examined some free Zoanthææ which were dredged by "H. M. S. 'Triton,' 640 Fuss" (1885, p. 481). Without paying any attention to the literature of the subject, he relegated these to a new genus, which he did not name. Very likely it is the Shetland species. Danielssen (1890) described specimens which he referred to Erdmann's new genus, which he named Mardell; and he called his new species *M. erdmanni* (p. 117). Through the courtesy of Dr. Danielssen we have been able to examine this form, and have cut sections of it. We are perfectly satisfied as to its specific distinction from the free variety of *E. incrustatus*.

The imperfect mesenteries of *E. erdmanni* are much more developed than in *E. incrustatus*; and there is almost invariably a well-marked lacuna in the mesogloea at the base of the insertion of each mesentery.

In every respect it is an Epizoanthus, the sphincter being mesogloéal instead of endodermal, as Danielssen states, and the arrangement of the mesenteries is macrocnemic, though Danielssen's figures do not show this.

**BRITISH SPECIES OF THE GENUS EPIZOA}NTHUS.**

*E. incrustatus*, Düb. & Kor., 1847.

*E. paguriphilus*, Verr., 1882.

*E. couchii*, Johnst., 1838.

*E. macintoshi*, n. sp.

*(E. rubricornis*, Holdsw., 1861.)*

*E. wrightii*, n. sp.

**SYNOPSIS OF BRITISH SPECIES OF EPIZOA}NTHUS.**

Forming carinææ, . . .

| One polyp ventral, remainder marginal, . . . . . . | *E. paguriphilus*. |
| Polyps on upper surface only, . . . . . . . | *E. incrustatus*. |
| Polyps radiating in one plane from a common point; diameter to height of polyp as 1 to 2, . . . . | *(E. rubricornis.)* |

Free colonies, . . .

| Polyps radiating in all directions from a common point; diameter to height of polyp as 1 to 4, . . . . | *(E. rubricornis.)* |

| a. Coenenchyme usually band-like, . . . . . . | *E. couchii*. |
| Diameter to height of polyp as 1 to 4, . . . . . | *(S. W. Ireland.)* |
| " " as 1 to 8, . . . . | *(S. W. England.)* |

Incrustating Colonies, . . .

| Coenenchyme probably band-like; diameter of polyp nearly as great as height, . . . . . . | *E. macintoshi*. |
| b. Coenenchyme irregular; diameter of polyp greater than height, . . . . . . . . | *E. wrightii*. |

The above relative proportions of diameter to height refers solely to contracted spirit specimens.
Epizoanthus incrustatus (Düüb. and Kor.).

(Pl. lviii., figs. 1–22 ; Pl. lix., fig. 2; Pl. lx., fig. 1.)

Spongia suberea:

Pysidea (?) papillosa:

Mammillifera incrustata:

Sidisia barleci:

Zoaanthus couchii:

Zoaanthusincrastatus:

Epizoanthus americanus:

Epizoanthus papillosus:

Polythoa arenacea:
Carus, 1884 (not of D. Ch.), Prod. Fauna Medit., p. 75.

Polythoa arenacea:
Andres, 1884 (not of D. Ch.), Le Attinie, p. 308. Pennington, 1885, Brit. Zooph., p. 182.

Epizoanthus conveiosius:

Polythoa incrastata:
Form.—Thickly incrusted forms, of which the well-grown polyps are twice as high as broad. Two well-marked varieties:—A. Incrusting form, ecrinenchyme forming carcineecium by replacement of a gasteropod shell; the two primary polyps at each end of the shell, usually forming a well-marked posterior marginal row of polyps; other polyps scattered on dorsal surface; maximum number about 10–12, varying much in height; no polyps on the under surface of the carcineecium. B. Free form, primarily consisting of two individuals base to base, each of which may divide more or less regularly, or one only may divide.

Colour.—Sandy.

Dimensions.—Polyps, 3–9 mm. in height; 1½–4½ mm. in average diameter. Colonies, greatest length, 22–35 mm.; greatest breadth, 13–20 mm.

Locality.—Shetlands; W. and S. W. Ireland; N. E. England; Lerwick (Barlee); 30 miles E. and N. of Brassey I., 70–80 faths. (Barlee); Haaf, Shetland, 1863 (A. M. N.); 5–8 miles E. of Balta, Shetland, 40–50 faths., July 20–23, 1867 (A. M. N.), "commensal with Pagurus levius" (Pl. lviii., figs. 1–13); also in St. Magnus Bay (A. M. N.); 40 miles S. W. of Cape Clear, Co. Cork, 80–90 faths., 1883, commensal with Eupagurus excavatus and Spiropagurus levius (A. C. H.); Nymph Bank, Co. Cork, 50 faths., 1886 (A. C. H.); Clew Bay, 1890; 33–40 faths. off Aran, Co. Galway, 1891 (A. C. H.), (Pl. lviii., figs. 14–22); 33–36, Donegal Bay, 1891 (A. C. H.); Scarborough (Bean, j. Johnston); Northumberland, "deep water" (Alder); 48° 50′ 42″ N., 10° 7′ 27″ W., 90 faths., 1889 (G. C. Bourne), associated with E. meticulous; Plymouth Sound (specimens in Mus. of Marine Biol. Assoc. Laboratory).

The geographical distribution of this species is North Atlantic, extending from the east coast of N. America to N. W. Europe.

The synonymy of this species is much involved, but we think the foregoing list is sufficiently complete. We agree with Norman in rejecting Johnston's specific name, as he considered it to be a sponge; and some years later (Hist. Brit. Zooph., 2nd ed., 1847, p. 202) he quotes Couch's description of Z. couchii, and has "the pleasure of naming this the only European Zoanthus after its discoverer." It is therefore clear that he did not regard his own form as a Zoanthan. We are thus obliged to adopt the specific name given to this species by Düben and Koren. Holdsworth, Gosse, and others have regarded this as a variety of E. couchii: we think that it will be admitted from our anatomical studies that this is not the case; neither can it be associated with E. arenaceus, D. Ch.

Owing to the kindness of Canon Norman we have been enabled to study some authentic Norwegian specimens of this species, and find them to be identical with the Shetland and Irish forms.

Dr. Gray had no hesitation in referring some specimens from the coast of Massachusetts, collected in forty-fathom water (Proc. Zool. Soc., 1867, p. 237), to
this species. Verrill, however, erected a new species for the forms dredged off the east coast of N. America. Thanks again to Canon Norman's courtesy we have examined some of Professor Verrill's specimens, and we must confess to not being able to distinguish them specifically from the European examples. It is difficult to understand why Professor Hertwig ignored these two specific names and adopted for his specimen (Challenger Sta., 49, off Nova Scotia, 85 fath.) the name of a form from the Pacific Ocean. Verrill (1885) says it (incrusting variety) ranges from "49-906 fathoms; abundant."

The synonymy has also been complicated on account of the occasional free habit. This variety was first named *Sidisia barleci* by Gray. Gosse, Holdsworth, and others have regarded it simply as a variety of the typically incrusting *Z. couchii*. Verrill, too, recognises a free and an incrusting variety of *E. americanus*, and also for his *E. abyssorum*; of this latter he says: "This species generally forms the carcinoma of *Parapagurus pilosimanus*, but sometimes consists of two or three large obconic polyps arising from a grain of sand" (l. c. 1885, p. 535).

Norman, however, in referring to this variety, says (1868, p. 319): "Taken abundantly in company with *Zoaanthus incrustedus*, of which I was at one time inclined to consider it a variety; but more careful examination and dissection has convinced me that there are certain distinctions between the two, besides the fact of *Sidisia* being a free-living, unattached form. Whether these distinctions are specific or sexual, a careful examination of the living animal must hereafter determine." We have compared microscopically the two varieties, and find them to be essentially similar.

**Incruising Form.**—Coenenchyme incrusting gasteropod shells inhabited by hermit-crabs, the shells being rapidly absorbed and replaced by the coenenchyme which thus forms the carcinoma. In old specimens the polyps appear to be irregularly arranged; but on an examination of younger specimens, three series of polyps can be distinguished. In the youngest example we have seen (Pl. LVIII., fig. 14) there is only a single polyp, which is situated at the apex of a small gasteropod shell, the shell itself being entirely coated by the coenenchyme. The second polyp arises at the oral axis, or hilum, of the shell (fig. 15). A third one usually makes its appearance above the mouth of the shell. We have seen several cases in which the apical polyp is in the act of fission (Pl. LVIII., fig. 12). These three polyps form the first series. The second series forms a marginal row which corresponds to the aboral varex of such a shell as *Ranella*. The third series forms an irregular row between the two former. In no specimen of the very large number we have examined is there a polyp on the under surface of the carcinoma. The polyps bend slightly towards the oral or anterior aspect of the carcinoma. In a contracted state the capitulum forms a
flattened disc-like termination to the polyp, on which indistinct radii, usually about 18 or 20 in number, can usually be discerned. The disc-like termination is sensibly of greater diameter than the column of the polyp.

Free Form.—The earliest stage we have seen consists of two polyps base to base. These may divide by fission more or less symmetrically (Pl. lviii., figs. 5—11), or one polyp may divide repeatedly, and the other not at all (Pl. lviii., fig. 2—4). The variations are so great that it would be impossible to attempt to describe them all; and we would here point out that the two species of Epizoanthus we have examined which have free forms (viz. *E. incrustatus, E. erdmanni*) vary in such a similar manner that the variations appear to have no taxonomic value; the same also holds good for *E. abyssorum*, Verr. We have seen specimens of similar varieties of other species which have not as yet been identified; one which comes from Naples will, we believe, be found to be a free variety of *E. arenaceus*. The size of the polyps and the character of the incrustations seem to be the only external features which distinguish the free forms of these species from each other, and these are obviously insufficient.

It is worthy of notice that the capitulum of the free varieties is usually less flattened than that of the incrusting forms.

The size which the polyps may attain apparently varies with the locality; for example, the largest of the Shetland specimens are 9 mm. in height, by 4·5 mm. in diameter; the largest colony from Balta measuring 30 × 20 mm.; that from Haaf being 35 × 20 mm. In the free variety the fully grown polyps average 6—7 mm. high, and 3—3·5 mm. across; the larger colonies being 22—23 mm. long by 8—11 mm. broad. From the S. W. of Ireland, the polyps range up to 7·5 mm. high by 3·5 in diameter, the carcinæcia being 24 × 15 mm. The W. of Ireland specimens from off Aran and from Donegal Bay run a good deal smaller: the polyps average 3—6 mm. in height and 1·5—3 mm. in diameter; most of the colonies are quite small, the largest being 22 × 13 mm. The nature of the incrustations also gives them a black-gray colour. The difference in size and colour between these and more normal specimens is so marked as to constitute a distinct variety.

Verrill’s original description (1866, p. 34) of this species (his *Epizoanthus americanus*, n. sp.) is as follows:—“This species, which is parasitic on shells, has an incrusting base, smooth and uniform on the lower side of the shell, but giving rise to from fifteen to twenty polyps on the upper side, which diverge in all directions. Polyps variable in height and size, those of the upper central portion generally half an inch in height (13 mm.) and one-eighth (3·25 mm.) in diameter; while those around the margin of the base are not more than half so large, and much crowded. Base spreading over and completely investing dead shells of Natica, Buccinum, &c., both externally and internally. The substance of the
shell in every case has been entirely removed, but the form in all parts is perfectly preserved by the membranes of the polyps, while the cavity is inhabited by a species of hermit crab (Eupagurus pubescens). Column pillar-like, smallest in the middle, increasing gradually below, but enlarging rapidly at the summit. Walls thin, covered by a layer of closely adhering fine sand. When contracted, the summit is slightly concave; and in the medium-sized polyps has seventeen, in the largest twenty-four sulcations, radiating from the centre, which is seldom completely closed. Tentacles, forty-eight or more, short, conical.

The localities at which this species had been obtained up to that time are given by Verrill in 1882, p. 316. The free or type-form (of E. americanus, Verr.) occurred at 28 stations, 28 to 487 fathoms, whereas the incrusting variety "(= Zoanthus norvegicus, Kor. & Dan.)" occurred at 11 stations, 69–160 fathoms. The former is by far the most abundant numerically. Later (1885), he gives the bathymetrical range of the free form as "26–547 fathoms; generally diffused and very abundant" (p. 534); and of the incrusting variety, "49–906 fathoms; abundant" (p. 535).

Smith and Harger (1874) report this species from off the coasts of New Jersey to the Gulf of St. Lawrence; the specimens with incrusted shells inhabited by Eupagurus pubescens came from 60–65 fathoms; while those from 430 fathoms were on stones and on hydroid stems. The figure, which is of a magnified polyp, is of no real value.

In Verrill's last Paper (1885, p. 60), he says it is mostly commensal with Eupagurus politus, Smith, and E. krøyeri, very common; those on grains of sand (free variety) were even more abundant. Some occurred incrusting sponges, shells, hydroids, tunicates, gorgonia, Paramuricea grandis, pebbles, &c. The original specimens off New Jersey, 30 fathoms, were commensal with E. pubescens. We think it possible that more than one species has been identified by our American colleague as E. americanus.

Body-wall (Pl. lix., fig. 2).—The incrustations in this species are numerous, and consist for the most part of coarse grains of sand, so that it is difficult to make out the structure of the body-wall from our sections. The ectoderm is continuous, and is covered by a cuticle, to which diatoms and dark granules are attached. Nematocysts, containing similar granules, are usually abundant in the ectoderm. The incrustations are embedded in the mesogloea throughout its entire thickness, often protruding into the cælenteron. Single cells are occasionally found enclosed in the mesogloea; and lacunae are sometimes found near the union of the mesenteries with the body-wall; but the mesogloea is for the most part devoid of cell enclosures. The usual endodermal muscular layer is present, being especially well-developed in the upper part of the column. The endoderm is formed by a thin layer of columnar cells of uniform height.
Sphincter muscle.—The mesogleal sphincter muscle is short, and consists of well-defined cavities.

Disc and Tentacles.—The disc and tentacles present the usual structure. The muscular layers appear to be feebly developed.

Eosophagus.—The shape of the oesophagus in cross-section varies in our specimens. Sometimes it is almost circular (Pl. lx., fig. 1), the groove forming a very slight depression; in other specimens the groove is fairly-well marked. The ectoderm is almost smooth, being but very slightly folded.

Mesenteries.—The arrangement of the mesenteries is macrocnemic. The imperfect mesenteries are very slightly developed, extending into the coelenteron but little beyond the endoderm. The ectoderm of the oesophagus is reflected, and forming a series of folds along each mesentery, is continued downwards in the usual manner to form the mesenterial filaments. The mesoglea of the mesenteries is slightly developed. The muscle-fibres form simple layers, there being no mesogleal plaitings. The endoderm of the mesenteries is thin, resembling that of the body-wall.

Gonads.—There were no gonads in the specimens examined by us.

Var. barleei.—The specimens we have cut of the free variety agree very closely in their anatomy with the above account; but the sphincter muscle appears to be longer and more powerful.

Epizoanthus paguriphilus.

(Pl. lvii., figs. 23–25; Pl. lx., fig. 6; Pl. lx., fig. 5.)

Epizoanthus paguriphilus:

Zoanthus (Corticantlius) paguriphilus:
Andres, 1884, Le Atinie, p. 326.

Form.—Colonies always forming carcinæa; slightly incrusted; mesoglea very thick; one polyp on ventral surface, the remainder forming a radiating single row, the "posterior polyp" of which is the smallest.

Colour.—Brownish in spirit specimens, but bluish-gray in colour where the thin incrustation is rubbed away.

Dimensions.—Average diameter of coenenchyme, 55 mm.; average height of polyps, 20–25 mm.; average width of polyps, 12–16 mm.; average thickness of polyps, 8–10 mm.

The geographical distribution of this species is North Atlantic, extending from the N. E. coast of America to N. W. Europe, in deep water.

This is the largest and most striking of the species of British Zoanthæ, and is quite a recent addition to our fauna.

The polyps are in two positions, one central and inferior, the remainder marginal, divergent, and uniserial. The cœnenchyme entirely surrounds the shell on which it grows, save for the orifice through which the commensal hermit-crab emerges. The orifice is ventrally situated, and is about 5 mm. distant from the anterior border of the carcinaecium, and is from about 15–20 mm. in diameter.

Immediately behind the orifice is a polyp, which in spirit-specimens does not rise above the general surface of the cœnenchyme, and is less than 10 mm. in diameter.

The marginal polyps are prominent, and elliptical in section. At the posterior end of the carcinaecium one polyp can readily be distinguished as being markedly smaller (15 mm. in height) than the other marginal polyps; this we term the "posterior polyp." There are in the three specimens which we have examined four well-grown polyps to the left of the posterior polyp, and four, five, and six, respectively, on the right side of the carcinaecium.

There is a space of 20 mm. between the right and left polyps on the anterior convex border of the carcinaecium. Under-surface of the carcinaecium flat; upper surface irregularly convex, with the greatest prominence towards the right.

A young specimen, which one of us dredged off the W. of Ireland, and which is drawn of the natural size in Pl. LVIII., fig. 25, shows that the order of the appearance of the polyps is probably as follows:—(1) the ventral polyp; (2) the posterior polyp; (3) the right and left anterior polyps; (4) the succeeding lateral polyps, of which the most posterior are the youngest. After four pairs of marginal polyps have appeared the further production of polyps appears to be confined to the right side.

This species is always commensal with Eupagurus pilosimanus.

Verrill first described this species in 1882 in the following terms:—"Polyps few and very large, stout, with broad, swollen bases, arising from a very thick, smooth, lubricous, gray or mud-coloured, translucent cœnenchyme, which at first invests small univalve shells, occupied by Parapagurus pilosimanus, but finally grows far larger than the shell, and eventually absorbs it. Disc broad, larger
than column; tentacles numerous, rather long, light orange. Breadth of colony, 2 to 3 inches; height of polyps in expansion, 1 inch or more; diameter, 5 to 7 of an inch" (p. 137). He further adds:—"Hitherto it has not been found elsewhere than upon the back of this particular species of crab, which, likewise, has not been found without its polyp. Of these associated creatures we took about 400 couples, at station 947, in 312 fathoms, at one haul. It had previously only been known by a few specimens taken by the Gloucester halibut fishermen, in deep water, off Nova Scotia, and by ourselves in 1880." On p. 316 of same journal (Am. Jour. Sci. (3), xxiii.) he adds:—"[Station 947, S. by W. 4 W, 89 miles off Martha's Vineyard, sand, mud, Aug. 9, 1881; temperature 44° Fr. U. S. Fish. Com. Rep. for 1882–1884, p. 643]." "Epizoanthus paguriphila, Verrill, sp. nov., 252–458 faths."—and gives a list of the stations at which it was obtained.

In the Bulletin Mus. Comp. Zool. Cambridge, Mass., Verrill gives the colour as translucent bluish or purplish-gray, or grayish-brown. In fresh specimens the tentacles are pale-orange or salmon, with lighter tips, and polyps more or less of a salmon-colour. The diameter of ordinary specimens, 60–70 mm.; vertical thickness, 25–30 mm.; length of polyps, 15–20 mm.; diameter in middle, 10–12 mm.; and at base, 12–18 mm. Some specimens considerably larger than this were obtained. There are seven to twelve polyps.

Body-wall (Pl. lix, fig. 6).—The ectoderm is not continuous, but is penetrated by strands of mesogloea, which unite (as in Z. coppingeri and other species of Zoanthus and of Isaurus, and also in G. macmurrichii, to form a peripheral layer of mesogloea. This peripheral layer of mesogloea is not distinguishable from the cuticle which covers the body. A more deeply stained outer layer may often be seen, but it appears to be simply due to the shrinking of the edge of mesogloea under the action of heat. The columnar cells of the ectoderm are closely packed, and stain deeply. They often contain dark pigment granules. Nematocysts filled with similar pigment-granules are frequently found amongst them. The few foreign particles (chiefly foraminifera and grains of sand) which incrust this species are generally found partly embedded in the ectoderm and partly in the adjacent mesogloea. The mesogloea is remarkably thick, being relatively much thicker than in any other species of Zoanthian examined by us. In section the mesogloea appears to enclose numerous "cell-islets." Some of these, however, are much elongated, and might possibly be regarded as forming parts of canals. We have not been able, however, to trace any distinct canals arising from either ectoderm or endoderm; and it seems more probable that all these cell enclosures are completely surrounded by mesogloea. The usual spindle-shaped cells drawn out into long fibres can be discerned running through the mesogloea. The endodermal muscular layer is not very well
developed; the fibres are supported on slight, rounded plaitings of mesogloea. The endoderm consists of a single layer of columnar cells, the peripheral portion of the cells being of a deep brown colour owing to the presence of pigment-granules.

*Sphincter muscle.*—The single mesogloëal sphincter is not a very powerful one. No cavities are visible, the fibres being completely embedded in the substance of the mesogloëa.

*Tentacles.*—The ectoderm of the tentacles is thrown into transverse folds. Numerous pigment-granules are to be found amongst the usual small nematocysts, and the nuclei in the peripheral portion. The muscular layer is not well developed. The mesogloëa forms an extremely thin layer. The endoderm is also pigmented.

*Disc.*—The disc is very similar in structure to the tentacles.

*Oesophagus.*—The ectoderm of the oesophagus is thrown into numerous folds. There is a well-marked groove. The mesogloëa forms a thin layer, except in the region of the groove where it is somewhat thicker. It contains a few cell-islets.

*Mesenteries.*—The mesenteries have the usual macrocnemic arrangement. The reflected ectoderm of the oesophagus is attached to them in the lower part of the oesophageal region and lower down forms the filaments as in other Zoanthææ. The mesogloëa is well developed in the oesophageal region, and here, on one side of each mesentery, plaitings which support the longitudinal fibres can be distinctly seen. Plaitings on both sides of the mesentery nearer to the body-wall which support the parieto-basilar fibres are exceedingly slight. The mesogloëa is much thinner in the lower part of the body. The endoderm is very similar to that which lines the body-wall.

*Gonads.*—The sexes are distinct. Male gonads are present in our sections; they are very numerous, and closely packed together, almost entirely filling up the body-cavity below the oesophagus (Pl. lx., fig. 5).

**Epizoanthus couchii** (Johnston).

(Pl. lviii., figs. 26–28; Pl. lix., fig. 4; Pl. lx., fig. 3.)

*Zoanthus couchii* :

(Dysidea (?) papillosa):

Carolia couchii:

Palythoa couchii:

Palythoa arenacea:
(Not of D. Ch.) Andres, 1884, var. couchii, Le Attinie, p. 308; Pennington, 1885, var. linearis, Brit. Zooph. (in part), p. 182.

Palythoa arenacea:
(Not of D. Ch.) Carus, 1884, Prod. Faunes Medit., p. 75.

Form.—Column cylindrical, rising to about three or four times its diameter. Margin cut into 12 or 14 (generally the latter number) large, fleshy, triangular teeth, which are connected by a thin web of transparent membrane. In a state of semicontraction these teeth form strongly marked, converging ridges on the flat summit of the column. Incrustations of fine sand. When the column is much distended, the grains of sand become considerably separated, and the visceral cavity can be seen through the transparent and smooth integuments. Disc, generally flat or slightly concave, but protusile in a conical form; radii distinct. Tentacles 28 (or 24), bicyclic, those of the inner row correspond to the marginal teeth; they are subequal, they taper gradually, are bluntly pointed, and about equal in length to the diameter of the column. Coenenchyme, narrow, irregularly creeping, soft, invested with sand like the column.

Colour.—Column and coenenchyme pale brown; disc pellucid, reddish-gray, dusted with excessively minute white specks; tentacles translucent, nearly colourless, opaque white tip; lip opaque white.

Dimensions.—"One-eighth of an inch [3 mm.] in diameter, and about thrice that height [9 mm.] in extension. In contraction the button is usually about a line [2 mm.] in height. Mr. Holdsworth has obtained specimens much larger than these."

Habitat.—"var. linearis.—The condition above described, in which the root-band creeps in a narrow ribbon over stones and shells. Cornwall and Devon."

The foregoing description is taken from Gosse, and refers to the specimens he had seen alive; perhaps he has incorporated older observations in it.

We have not been able to see any specimens of this species from the recorded localities, although we have made numerous efforts to do so. Our generous friend Canon Norman put some Zoanthese from the Channel Islands at our disposal, which bear a very strong superficial resemblance to E. couchii, as defined
above; unfortunately they had been dried at some time or other, although they were in spirit when we had them, and though we made sections of them we could not make any satisfactory observations.

In order to facilitate the work of future observers we abstract all the additional information about this species, which is valuable from a descriptive point of view.

Johnston (1847) defines the genus and species as follows:—"Zoanthus: polypes distant, united by a creeping, root-like, fleshy band. Z. couchii: body cylindrical; tentacula in several circles." In quoting from Couch he adds the following details:—"It is a very small species ... of a light sandy or opaque red colour, and its surface is minutely glandular [this is an error of observation, and probably refers to the grains of quartz]. In its contracted state it is sub-conoidal, resembling both in shape and size a split pea. When semi-expanded it elevates itself to about twice its former height, and becomes contracted about its middle into an hour-glass form. When fully expanded the tentacula become distended and elongated to about the length of the transverse diameter of the body; and they are generally darker at their extremities than towards the base."

Holdsworth (1858) obtained some specimens from 10–12 fathoms off Torbay. "One group of six polypes on the inside of a valve of Cardium rusticum is arranged in a linear series; ... others are scattered over the surface of a flat stone, and have no perceptible connexion with one another, except in a few instances when two or three of them are united. ... The body forms a cylinder from 2 to 4 lines [about 4.5–9 mm.], by about half that in breadth, and is clothed with a dense coating of fine sand, which at the upper extremity is divided into 14 deeply-cut, marginal teeth; these cover the top of the column when the animal is closed. The tentacula are moderate in length, slightly tapering, smooth. ... They are arranged in two rows containing 14 each, of which the inner series are rather the longer, and are placed opposite the angular prolongations of the column, those of the outer row alternating with them. ... The general colour of the disc and tentacula is a pale transparent brown, becoming opaque white around the mouth and at the tips of the arms, and all the intermediate parts are finely speckled with the same tint." The following year (1859) he obtained some much larger specimens from Torbay.

Hincks (1861) says, "Not uncommon: Salcombe Bay [Devonshire], on slate, stone, &c. (in about 12–15 fathoms)."

The following is a description of an Epizoanthus dredged by one of us in the S. W. of Ireland, and which we refer with some hesitation to this species. If E. rubricornis should prove to be a different species from E. couchii, our form will probably be found to be the same as the former, although the tentacles are of a different colour, and the habit of growth is different.
Form.—The column is elongated, tapering from above downwards; the body-
wall is well incrusted, but when the sand is rubbed off, the body-wall is thin and
translucent. The capitulum has about 14 ridges; these may be present or absent
in preserved specimens; in the latter case their absence appears to be due to their
being rubbed when in the dredge. Tentacles bicyclic, about 14 in number in
each cyle, the inner being slightly the longer and more curved. Mouth linear, on
a slight cone. Cœenchyme, thin, either band-like, or forming small expansions.
Colour.—Sandy, sometimes dull, tawny-orange when alive; disc translucent
buff, lips white, pale radii; tentacles translucent buff, opaque-white spot at tip.
Dimensions.—Usually about 10–14 mm. in height, and 2–3 mm. in diameter at
the top of the contracted specimens, occasionally reaching a height of 18–20 mm.,
with a diameter of 4·5–5 mm.

Habitat.—S. W. Ireland; about 30 miles off Cape Clear (Pl. lviii., figs.
27, 28), 80 fathoms; 40 fathoms off Glandore, Co. Cork; Berehaven, Bantry
Bay, 10 fathoms (A. C. H.), (Pl. lviii., fig. 26), [Proc. Roy. Irish Acad. (2), iv.,
Sci., 1886, in which Report Mr. S. O. Ridley identified this form as Palythoa
arenacea (?), D. Ch., p. 617].

The Rev. Canon Norman has sent us specimens of an Epizoanthus from
Birterbuy Bay, Co. Galway. They were unfortunately too badly preserved for
us to be able to study them minutely, but at all events the sphincter muscle
closely resembles that of our specimens from S.W. of Ireland, and externally
they agreed fairly well with the English specimens of this species. Some very
similar Channel Island specimens (identified as "Z. couchii"), which he gave us at
the same time, probably belong to this species.

Fischer's (1874) description is as follows:—"The base of the colony is clothed
with a layer of agglutinated sand, extending more or less; the polyps, irregularly
disposed, have their column protected by a coating of sand; this is cylindrical and
elongated when completely extended; colour cindery-gray; the superior border has
14 to 15 teeth. The tentacles, disposed in two rows, are short, whitish, and to the
number of 28–30. The disc is whitish; the mouth small, transverse."

The specimens came from "Arcachon, from 20–45 brasses. The colonies were
fixed on to the shell of Chenopus pes-pelicant, which gives lodging to a Sipunculus.
Alder has identified it at Guernsey. M. Sauvage has obtained it at Boulogne on
Pecten maximus, dredged in the channel" (p. 235). In his "bathymetrical distri-
bution" he records this species on the oceanic coasts of France, from the Nullipore
zone (28–72 metres), p. 239. The other Papers are merely abstracts.

To sum up the history of this species we may put the present state of our
knowledge in this form. Johnston quotes Couch's description of the Cornish type
specimens. Gosse, Holdsworth, and Hincks obtained Devonshire specimens which
are probably the same as the former. Forbes identifies it as having been dredged
by MacAndrew in Loch Fine, W. Scotland, in 1844. Thompson records it as having been dredged by himself and Hyndman in 1835 and 1846, 15–20 fathoms, from Strangford Lough (N.E. Ireland). Wright and Greene copy this. It may or may not be this species. We now describe specimens from S. W. Ireland which may possibly be this species: Fischer identifies it from the N. and W. coasts of France. Andres and Pennington merely quote Gosse.

**Body-wall** (Pl. lix., fig. 4).—The body-wall is extremely thin in this species. The ectoderm, where present, is continuous, and is covered by a thin cuticle. It contains occasional nematocysts. Incrustations, which consist chiefly of grains of sand, are fairly numerous. Cell-enclosures are very rare. The endoderm is very thin, and of uniform thickness. The muscular layer is rather feebly developed.

*Sphinctor muscle.*—The single mesogleal sphincter is well developed, although it is not so powerful as in the free variety of *E. incrustatus*. It consists of elongated cavities which are well filled with muscle-fibres, the cavities forming for the most part a single row (Pl. lix., fig. 3).

**Disc and Tentacles.**—The structure of the disc and tentacles is for the most part as in other species of Zoanthæ; but oval nematocysts, similar to those which are found in the ectoderm of the body-wall and of the oesophagus, are present in the ectoderm of the tentacles of more than one of the specimens which we have cut. We have not, however, found them in all our specimens.

**Oesophagus.**—The ectoderm of the oesophagus is thrown into folds which appear to be deeper as a rule in the short than in the longer specimens. There is a well-marked groove. Nematocysts are generally to be found in this region; but in one or two specimens we have not been able to find them. In some cases they are very abundant. Sometimes they appear to contain black pigment-granules. In other cases they are quite clear, containing a distinct, coiled thread.

**Mesenteries.**—The mesenteries present the usual macrocnemic arrangement. The imperfect mesenteries are fairly well-developed. The longitudinal muscles are borne upon mesogleal plaitings which are frequently well-marked, but in some of our specimens they are much slighter than in others. Nematocysts are very abundant in the ectoderm, which forms the mesenterial filaments in the usual manner.

**Gonads.**—We found no gonads in any of our specimens.
Epizoanthus arenaceus (D. Ch.), (not British, Mediterranean). (Polythoa (str. s.) arenacea. Andres, 1884, p. 308. Type var. Palythoa arenacea, Carus, 1884, p. 75.)

(Pl. lix., fig. 7; Pl. lx., fig. 4.)

Form.—Column cylindrical. Body-wall, thick and opaque, sometimes transversely wrinkled, about 15 capitular ridges and 30 tentacles; cœnenchyme incrusting, with a tendency to form linear bands.

Colour.—Dirty sand (in spirit).

Dimensions.—Height, 7-12 mm.; diam., 3·5-4·5 mm.

The above description is taken from specimens identified at the Naples Zoological Station. It will be seen that E. arenaceus differs from E. couchii, chiefly in the great thickness of its body-wall, which gives it a very characteristic appearance (Pl. lix., fig. 7). Our specimens were not well preserved, and we have therefore some difficulty in determining satisfactorily anatomical characters. The mesogloea sphincter muscle differs from that of E. couchii in the appearance of its cavities, the muscle-fibres being arranged in a single row round the mesogloea, leaving an empty space in the centre of the cavity (Pl. lx., fig. 4). The thickness of the body-wall can be well seen in transverse sections. Nematocysts are present in the ectoderm of the œsophagus, and in the mesenterial filaments.]

Epizoanthus macintoshii, n. sp.

(Pl. lviii., fig. 29; Pl. lix., fig. 1.)

Form.—Short, very stout, rigid column, incrusted with foraminifera which give it a very characteristic, white, granular appearance. Upper surface of contracted column with 18 radial ridges. Cœnenchyme apparently linear, of same nature as the wall of the column.

Colour.—Grayish white.

Dimensions.—(In spirit) one polyp, 7 mm. high by 6 mm. in diameter; the other, 5 mm. high by 4·5 mm. in diameter.

Locality.—Shetlands (1871).

A small colony of three specimens of this species was kindly handed over to us by Dr. W. C. M‘Intosh, F.R.S., Professor of Zoology at St. Andrews. One of these we devoted to the microtome; the remaining specimens are in Prof. M‘Intosh’s collection. We are pleased to be able to associate such a well-marked species with the distinguished Scottish Zoologist who has placed his collection of Actiniae at our disposal.
Body-wall (Pl. lix., fig. 1).—The ectoderm is much broken, owing to the incrustations. Where present it is continuous, and is covered by a thin cuticle. Thread cells, containing a few, almost black, pigment-granules, are occasionally to be met with amongst the columnar cells of the ectoderm. The mesogloea is thinner relatively to the diameter of the column than in most species of Zoanthæ. The incrustations consist almost exclusively of foraminifera, which are frequently so large that a single specimen extends right across the body-wall, and is partly embedded in the ectoderm and partly in the endoderm, as well as in the mesogloea. There are hardly any cell-enclosures in the mesogloea. Single cells only are occasionally to be seen enclosed. The endodermal muscular layer appears to be fairly well developed. The endoderm is formed by a thin layer of columnar cells of uniform height.

Sphincter muscle.—The single mesogloëal sphincter is thick, extending right across the wall of the capitulum. The cavities in the mesogloëa are large.

Disc and Tentacles.—The nuclei of the ectoderm are diffused, and do not form a central band. The muscular layers are well developed.

Oesophagus.—The ectoderm of the oesophagus appears to be quite smooth, not being thrown into folds. The groove is well marked, and there is a slight thickening of the mesogloëa in this region.

Mesenteries.—The arrangement of the mesenteries is macrocnemic. Owing to the presence of a parasitic crustacean in the single specimen we have cut it is difficult to determine the details regarding the mesenteries. The imperfect mesenteries extend but a short way into the body-cavity. The mesogloëa is well developed, and is thrown on one side of each mesentery into distinct plaitings, which support the longitudinal muscle-fibres. The parieto-basal muscles are less well developed, and appear to extend but a short way from the body-wall.

Gonads.—We found no gonads.

Parasitic Crustacean.—It is impossible to determine the nature of the crustacean infesting our specimen, or to say whether it is a fully developed or a larval form.

[Epizoanthus norvegicus (Kor. & Dan.).] (Not British, Norway.)

(Pl. lix., fig. 5.)

Form.—Rather more clavate than E. macintoshi; cœnenchyme forming expansions, in which the polyps, in the specimens we have examined, appear to have a tendency to form linear series.

Colour.—Sandy brown (in spirit).

Dimensions.—Height, 6-12 mm.; diam., about 6 mm.
We are again indebted to our friend Canon Norman for specimens (identified by Danielssen) of this species. Outwardly it differs from *E. macintoshi* in the rather more clavate form mentioned above, and in the darker and more brownish colour. Our specimens of either species are not sufficiently numerous to lay much stress on the difference in the cœnenchyme, which in many species varies much according to the nature of the body to which the polyps are attached. Anatomically the two species can be readily distinguished. The ectoderm of the body-wall in *E. norvegicus* is very thick, and is crowded with nematocysts (Pl. lix., fig. 5). In *E. macintoshi* the ectoderm is very thin relatively to the diameter of the column, and contains very few nematocysts (Pl. lix., fig. 1). The incrustations in *E. norvegicus* are various, consisting of spicules, grains of sand, and foraminifera. In *E. macintoshi* they consist almost exclusively of foraminifera. The endoderm also in *E. norvegicus* is much thicker than in *E. macintoshi*. The imperfect mesenteries in *E. norvegicus* are remarkably well developed. In *E. macintoshi* they are feebly developed, extending a very short way into the body-cavity.]

**Epizoanthus wrightii**, n. sp.

(Pl. lviii., figs. 30–33; Pl. lix., fig. 3; Pl. lx., fig. 2.)

*Form.—* Column somewhat thick-set, body-wall incrusted but not particularly rigid, 16 capitular ridges, mouth a narrow slit, with one oesophageal groove; tentacles 32 in number, bicyclic, transversely corrugated when not fully extended. Cœnenchyme broad, flat, irregular. Polyps arise from the cœnenchyme; craspeda ejected from the mouth when irritated.

*Colour.—* Dirty pellucid-white or orange-pink; in both the disc is speckled with opaque white; tentacles with an opaque white tip; craspeda, white or orange-pink, according to the colour of the polyp.

*Dimensions.—* Height, 13 mm.; diameter of column, 8·5 mm.; diameter of disc, 13 mm.; length of tentacles, 13 mm. Average height of expanded spirit specimens, 4 mm.; average diameter of column, 3 mm. In the contracted specimens the height and diameter are about equal, or the latter may even be the greater.

*Habitat.—* Dalkey Sound, Dublin Bay; between tides; spreading over incrustations on the granite rocks but never actually attached to the granite itself.

We are indebted to the brothers Dixon, for these specimens, and the above description is mainly taken from an account recently published by them ("Notes on the Marine Invertebrate Fauna of Dublin," Proc. Roy. Irish Acad., ser. iii., vol. ii., p. 29, 1891). They very kindly placed all their specimens at our disposal. We have the pleasure of dedicating this species to our friend Dr. E. Perceval
Wright, who is so well-known as a student of the Actiniozoa, and who is always so ready to help his scientific colleagues.

*Body-wall* (Pl. lix., fig. 3).—The ectoderm, where present, is continuous. It consists of numerous granular and deeply staining columnar cells, with occasional nematocysts scattered amongst them. It is protected by a thick cuticle, which does not stain but is of a dark brown colour owing to the presence of dark brown granules and of various foreign bodies. Incrustations chiefly consisting of coarse grains of sand, with a few foraminifera, are embedded in the mesogloea, which contains very few cell-islets or other enclosures. The endoderm is formed by a rather thin layer of ordinary columnar cells. The endodermal muscular layer appears to be but slightly developed.

*Sphincter muscle.*—The single mesogloea sphincter consists of several rows of simple cavities at the distal end. Proximally it is reduced to a single row of very small cavities (Pl. lix., fig. 2).

*Disc and Tentacles.*—There is little worthy of note in the structure of the disc or tentacles. Both ectodermal and endodermal muscular layers are well developed.

*Esophagus.*—The ectoderm of the esophagus is thrown into well-marked folds; there is a distinct groove, but little if any thickening of the mesogloea in this region.

*Mesenteries.*—The mesenteries have the usual macrocnemic arrangement. The imperfect mesenteries are distinct, although they extend but a short way into the body-cavity. The reflected ectoderm forms the mesenterial filaments in the usual way. The mesogloea is not very well developed; both parieto-basilar and longitudinal muscles form almost simple layers. The endoderm is thinner than that of the body-wall, and contains in addition to the ordinary columnar cells, small oval cells which stain a very deep carmine.

*Gonads.*—No gonads were present in the specimens examined by us.

**PROBABLY BELONGING TO THIS GENUS.**

*Zoanthus rubricornis,* Holdsworth.

*Zoanthus rubricornis*:

*Polythoa (Endeithoa) rubricornis*:
Andres, 1884, Le Attinie, p. 816.

*Form.*—An unattached group of ten polyps, each gradually tapering from above downward, incrusted with sand; marginal serrations not nearly so conspicuous as in *E. couchii*. 
Colour.—Tentacles a distinct red.

Dimensions.—Largest polyp, 25 mm. in height, and about 5–6 mm. diameter at the top when contracted. (Judging from the figure, 20 mm. is the average height, and 5 mm. the capitular diameter.)

Habitat.—Plymouth Sound.

This species has apparently never been met with since its discovery; and we are unable to do more than recast Holdsworth's description. We have no doubt that this species is an Epizoanthus; and it very closely resembles in outward appearance the specimens of E. couchii, which one of us has dredged off S.W. Ireland, the habit of growth being the most distinguishing feature, and upon this we do not place any reliance. Should this species be found to be distinct from E. couchii we expect that our Irish specimens would have to follow the former.

PARAZOANTHUS, n. g.

Macrocnemic Zoantheae, 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 mesogloea. Dioecious. Polyps connected by thin coenenchyme.

This is a very well marked genus anatomically; but it is often impossible to distinguish between certain species of this genus and those of Epizoanthus on external examination only.

We have taken for our type P. axinellaæ (Schmidt), as this form is so readily obtainable, and, thanks to the Naples Zoological Station, is to be found in most museums. Another advantage is that it is one of the easiest of the incrusted Zoantheæ to study microscopically.

Erdmann was the first to separate the macrocnemic Zoantheæ, with a diffuse endodermal sphincter, from those with a mesogloal muscle. He rightly retained the genus Epizoanthus for the latter, but wrongly referred the former to Palythoa, of which he also took P. axinellaæ as the type. We have elsewhere (1891) entered into a detailed discussion of our reasons for restoring Palythoa to its type species P. mammillosa (E. & S.), and we consequently have to erect the new genus defined above.

BRITISH SPECIES OF THE GENUS PARAZOANTHUS.

P. anguicoma (Norman), 1868.

P. dixoni, n. sp.
SYNOPSIS OF BRITISH SPECIES OF PARAZOANTHUS.

(EXTERNAL CHARACTERS.)

Coenenchyme thin, band-like, or inconsiderable; capitular ridges about 18, prominent, granulated, ................................................................. P. anguicoma.
Coenenchyme thick, soft, expanded; capitular ridges about 21; not so prominent as in former, ................................................................. P. dixoni.

(ANATOMICAL CHARACTERS.)

Mesenteries project only a short distance from the body-wall into the celenteron; endoderm of moderate thickness, uniform; incrustations numerous, ................................................................. P. anguicoma.
Mesenteries project a considerable distance from the body-wall into the celenteron; endoderm forming very thick ridges between every two mesenteries; incrustations few, ................................................................. P. dixoni.

The following species is inserted for comparison with the above:—

Coenenchyme thin, band-like or irregular expansions; capitular ridges 13-15, not very prominent, ................................................................. P. axinella
Mesenteries much as in P. anguicoma; endoderm very thin and uniform; incrustations not very numerous, chiefly spicular, ................................................................. (Mediterranean).

Parazoanthus axinellae (Schmidt).

Type species.—(Not British.)

(Pl. LIX., fig. 8; Pl. LX., figs. 6, 7.)

Palythoa axinellae:

Zoanthus axinellae:

Polythoa (str. s.) axinellae:
Andres, 1884, Le Attinie, p. 311, pl. x., fig. 7.

Form.—Polyps obconical, coated with foreign particles; capitular ridges, 13-15, not very distinct. Tentacles, 26-30; pointed with a very slight
terminal swelling, perforated. Cœnenchyme band-like, linear, adhering to sponges; polyps usually in linear groups of three or four, sometimes solitary.

*Colour.*—Yellowish.

*Dimensions.*—Height, 7 mm.; diameter, 3 mm.; tentacles, 5–10 mm.

*Habitat.*—On various sponges, also on corallines and stones. Adriatic, Marseilles, Naples.

The foregoing description is compiled from the accounts given by Andres and Carus. In the specimens we have examined, as sent out by the Naples Zoological Station, we find that there is a considerable variation in the size of the polyps, some attaining a height of 13 mm., and the cœnenchyme forms an irregular expansion on which the polyps are very crowded. The following anatomical account is based upon these specimens. We leave it for others to determine whether more than one species is commonly identified as *P. axinella*. Koch’s specimens appear to be the same as ours, so far as his description and figures go. The Adriatic specimens require re-investigation.

*Body-wall* (Pl. lix., fig. 8).—The body-wall is covered with a delicate cuticle, beneath which lies a rather thin layer of continuous ectoderm. Numerous oval nematocysts, which do not stain, are generally to be found among the granular and deeply staining columnar cells of the ectoderm. Incrustations, consisting for the most part of sponge spicules, are scattered, sometimes thickly, sometimes more sparingly, through the mesogloea. Beneath these incrustations, separated from the endoderm by a thin layer of mesogloea, lies an encircling sinus, containing deeply staining nuclei and cell contents, as well as numerous nematocysts similar to those which are found in the ectoderm. The sinus is frequently interrupted by bars of mesogloea of variable thickness, so that in cross section it often appears to consist of a circular series of rather narrow lacunæ. Canals frequently branch off from the sinus, and in many cases their connexion with the ectoderm can be distinctly seen. Single isolated cells are occasionally found enclosed in the mesogloea. The endoderm forms a very thin and almost uniform layer.

*Sphincter muscle.*—The sphincter muscle is, as described by Erdmann, diffuse and endodermal.

*Disc and Tentacles.*—There is nothing worthy of special note in the structure of the disc and tentacles.

*Oesophagus.*—The groove is well marked, and the mesogloea is considerably thickened in this region (Pl. lx., fig. 6).

*Mesenteries.*—The arrangement of the mesenteries is macrocyclic. The imperfect mesenteries are well developed, often reaching nearly half way from the body-wall to the oesophagus. The longitudinal muscles are well developed in the upper part of the mesenteries, close to the disc, the fibres being supported in this
region by well developed mesogleal plaitings. Lower down the plaitings disappear, the muscles forming an almost simple layer. Close to the disc a bundle of transverse fibres are seen on the opposite side of each mesentery to that which bears the longitudinal fibres. These seem to be the prolongations of the endodermal muscles of the disc and tentacles. The reflection of the ectoderm of the oesophagus, and its connexion with the filaments, can be well seen in this species (Pl. lx., fig. 6). The mesoglea and the endoderm appear to be involved to some extent in the reflection also. The endoderm of the mesenteries forms, for the most part, a very thin layer, but it is much thickened in the region of the filaments (Pl. lx., fig. 7), the mesenteries in this region resembling those of Z. macgillivrayi (Pl. lxiv., fig. 8), but the thickening is not so marked as in that species, nor do we find here either zooxanthellae or nematocysts.

**Gonads.**—In one of our specimens male gonads are present. They are surrounded by a thickened layer of endoderm (Pl. lx., fig. 7).

**Parazoanthus anguicoma** (Norm.)

(Pl. lviii., figs. 34—36; Pl. lx., figs. 11, 12.)

*Zoanthus sutchus*?:


*Zoanthus anguicoma*:


*Polythoa (Taniotioha) anguicoma*:

Andres, 1884, Le Attinie, p. 317.

*Polythoa, sp.*:


*Polythoa anguicoma*:


**Form.**—Body rigid, rough; in some specimens the column has an almost warty appearance; capitular region swollen when contracted; radial ridges about 18 in number, prominent, rough. Tentacles in two eyles, of about 17 in each, very long and extensile, more than equal to diameter of disc when fully expanded; gradually attenuating to very slender points. Coenenchyme incrusted, thin, either band-like, creeping on sponges and other objects, or forming broader expansions. The coenenchyme is never well developed, and sometimes the polyps are isolated or in small groups. The smaller specimens, when contracted, have a button-like appearance.

**Colour.**—Pinkish-white (Norman); sand colour in preserved specimens.
Dimensions.—"Column, 3–5 times as high as broad" (Norman). Height of column, when fairly extended (in spirit), 13 mm.; diameter of withdrawn capitulum, 3–4 mm. In the "button" condition the height is much less, about 4–5 mm., or even less. Some West of Ireland specimens have, in spirits, a height of 15 mm., diameter of capitulum 5–6 mm., diameter of middle of column 3–4 mm.

Locality.—Shetlands, W. and S.W. Ireland. The exact localities for this species are as follows:—"Living on sponges, *Phakellia ventilabrum* and *P. robusta, Normania crassa, Oceania pia jeffreysii*, &c., in very deep water, 110–170 faths., 20–25 miles N.N.W. off Burrafarth Lighthouse" (A.M.N.), (Pl. LVIII., fig. 34); St. Magnus Bay, Shetland, 1867; "Porcupine, 1869, St. 8, 100–159 faths." [off Galway Bay, W. Ireland]. The foregoing are in Canon Norman's collection. 80 faths., 40 miles S.W. of Cape Clear, Co. Cork, 1885 (A.C.H.), (Pl. LVIII., fig. 36); 80 faths., off the Skelligs, Co. Kerry, July 13, 1886 (A.C.H.), (Pl. LVIII., fig. 35); 126 faths., off Achill, Co. Mayo, 1890 (A.C.H.).

This species is subject to considerable variation in general appearance, so much so that we at one time thought that the forms we had under review might belong to two species. This is the "squat button-like form" of Ridley (i.e.). There can be no doubt that this is the "Desmacidon jeffreysii, from Shetland," of Bowerbank. Hertwig (1888, Suppl. "Chall." Rept. Actiniaria, pp. 446–48) doubtfully refers a colony of "Palythoa" to this species from Inaccessible Island, Tristan d'Acunha (S. Atlantic), 60–90 faths. From Erdmann's anatomical investigations of these specimens it is certain that they belong to the genus Parazoanthus. The species is certainly very close to *P. anguicoma*; but we consider that the slight differences in the external characters, together with the "considerable hollow expansion" of the encircling sinus ("ring-canal") invariably opposite the insertion of the mesenteries, are sufficient to separate the two species, and for the latter we would propose the name of *Parazoanthus hertwigi*.

Body-wall (Pl. LIX., figs. 11, 12).—The ectoderm, where present, is continuous, and is covered by a thin cuticle. It forms a layer of variable thickness, and consists of columnar cells containing deeply staining granules, and of oval nematocysts which do not readily stain. Incrustations, consisting of sand spicules, foraminifera, &c., are fairly numerous, and are embedded both in the ectoderm and in the mesogloea. There is a well-developed encircling sinus, which lies beneath the incrustations. It is of variable thickness, and is frequently crossed by strands of mesogloea; but these strands are not at all so thick as those in *P. axinella*, and the sinus in consequence presents a much less broken appearance than in that species. Branching and anastomosing canals, very similar to those which we describe for *Z. coppingeri* (1891), connect the encircling sinus with the ectoderm. Nematocysts are frequently to be found in the encircling sinus.
Cell-islets and lucanae are also often enclosed in the mesogloea. The endoderm forms a thin layer of almost uniform thickness. The diffuse endodermal muscular layer is well developed.

_Sphincter muscle._—The sphincter muscle is diffuse and endodermal, as in other species belonging to this genus. The mesogloeaal plaitings are deep and well developed, but they branch very slightly.

_Disc and Tentacles._—There is little worthy of special note in the structure of the disc and tentacles. The ectodermal muscles are exceedingly well developed.

_Oesophagus._—The ectoderm of the oesophagus is generally thrown into folds, but these are in some cases very slight. There is generally a well-marked groove, the mesogloea being here somewhat thickened. Occasionally cell-islets are to be found in this region.

_Mesenteries._—The arrangement of the muscle is macrocnemic. The imperfect mesenteries generally extend well into the coelenteron. The longitudinal muscles vary considerably in the degree to which they are developed, not only in individuals, but in different parts of the same individual. In some cases they form an almost simple layer, whilst in others they are supported on well-developed plaitings of the mesogloea. The filaments are formed by the continuation of the ectoderm in the usual manner. Immediately below the oesophagus, the perfect mesenteries, bearing the filaments, extend but a short distance into the coelenteron, leaving considerable empty space in the centre. Lower down they again increase in size, and near the base of the polyp they contain sinuses which appear to be of the same origin as the ectodermal enclosures of the body-wall.

_Gonads._—There were no gonads in the specimens of this species which were examined by us.

**Parazoanthus** *dixoni*, n. sp.

(Pl. lviin., figs. 37, 38; Pl. lix., figs. 9, 10; Pl. lx., figs. 8, 9.)

_Form._—Body long, cylindrical, or quite short, smooth, or slightly roughened, very few incrustations. Polyps crowded, springing irregularly in all directions from an expanded, soft, thick coenenchyme. Buds often arise from close to the bases of the older polyps. Scarcely any diminution in the length of the contracted polyps is noticeable as compared with the expanded specimens. The upper end of the contracted specimens is swollen, and has about 21 inconspicuous

* We name this species in honour of our friends the brothers G. Y. and A. P. Dixon, who have done much valuable work in connexion with the Irish Actiniae.
radial ridges. Disc with distinct radii; mouth ellipsoid, lips prominent. Tentacles in two cycles of about 21 in each; length about the diameter of the disc.

Coloured—Creamy white; polyps with a slight pinkish tinge.

Dimensions.—(In spirit). A. The larger specimens: height of column, 20 mm.; diameter, 4–5 mm.; diameter of disc and tentacles, 10 mm.; the mesogloea of one colony measured 60 mm. by 30 mm. (Pl. LVIII., fig. 37). B. Medium specimens: height of column, 16 mm.; diameter, 3 mm.; average diameter of disc and tentacles, 9 mm. C. Small variety: average height of column, 5 mm.; diameter, 4 mm. (Pl. LVIII., fig. 38).

Locality.—West of Ireland (5–8 miles W. of the Great Skellig, Co. Kerry, 70–80 fath., July 13, 1886. A. C. H.). This species was also obtained by the "Porcupine" in 1869. (No locality. Norman collection).

Body-wall (Pl. LIX., figs. 9, 10).—The ectoderm is continuous, and is covered by a thin cuticle. It forms a thick layer, consisting of very granular columnar cells, which stain deeply, and of numerous nematocysts which do not stain. The nematocysts in this species are scattered throughout the ectoderm in a fairly uniform manner. Incrustations consisting of spicules, grains of sand, and foraminifera may be found scattered at intervals through the mesogloea, but in our specimens of the larger variety these are very rare. Beneath the incrustations lies a well-developed encircling sinus. It is frequently broken by strands of mesogloea, and is connected with the peripheral ectoderm by numerous branching and anastomosing canals, very similar to those we find in P. anguicoma. The encircling sinus is connected with the endoderm by the fibrils or canaliculi of the mesogloea, which are numerous and very distinct in our sections. The endoderm is not of uniform thickness as in P. anguicoma, but becomes very thick in the centre of each endocoele and ectocoele, thus forming a longitudinal ridge between every two mesenteries. The diffuse endodermal muscular layer is well developed.

Sphincter muscle (Pl. LX., fig. 8).—The diffuse endodermal sphincter is well developed, but very simple in character, the mesogloea being raised into distinct but unbranched plaitings. In some sections some of these plait appear to unite so as to enclose part of the muscle entirely in the mesogloea, but we are uncertain whether this appearance is not due to the direction in which the sections are cut.

Disc and Tentacles.—There is little worthy of note in the structure of the disc and tentacles. The ectodermal muscular layer is well developed.

Oesophagus.—The ectoderm of the oesophagus is thrown into deep folds, into which the mesogloea also enters. There is a deep, well-marked groove, and the mesogloea is here very much thickened.

Mesenteries.—The arrangement of the mesenteries is macrocnemetic. The imperfect mesenteries are well developed, and extend into the body-cavity nearly half-way between the body-wall and the oesophagus. The ectoderm of the
oesophagus is connected with the filaments in the usual manner. The mesogloea of the mesenteries is well developed in all our specimens, and is thickened as well as raised into distinct plaitings on that side of each mesentery which bears the longitudinal muscle fibres (Pl. ix., fig. 9). The parieto-basal muscles are not so well developed as the longitudinal ones; and they extend along each side of the mesenteries, but a short way into the coelenteron; there is therefore no difficulty in distinguishing between the two sets of muscles; and the pairing of the mesenteries can be very distinctly seen in this species. The endoderm of the mesenteries is thinner than that of the body-wall. The perfect mesenteries, from the termination of the oesophagus downward, extend far into the coelenteron, which is, in consequence, almost filled up by the mesenteries and their filaments. Transverse sections of *P. dixoni*, taken just below the oesophagus, present in consequence a very different appearance from those of *P. anguicoma* taken from the same region. In our specimens of the small variety we find well-marked sinuses in the mesogloea of the mesenteries, extending from the cemenenchyme a short distance upward into the coelenteron, disappearing at about the lower termination of the mesenterial filaments. These sinuses are very similar in appearance to the ectodermal sinuses of *Z. coppingeri*, but we are unable to find in them any connexion with the ectodermal canals of the body-wall, whilst in several places they appear to be distinctly connected with the endoderm. We do not find these sinuses in the mesenteries of any of those specimens of the larger variety of *P. dixoni* which we have cut.

**Gonads.**—We have found no gonads in our specimens of this species.

**OF UNCERTAIN POSITION.**

**Zoanthus sulcatus**, Gosse.

*Zoanthus sulcatus*:


*Gemmarea (?) sulcata*:


*Palythoa sulcata*:


*Polythoa (Tanithoa) sulcata*:


**Form.**—Column generally cylindrical, but versatile; upper third of extended column free from sand, and indented with twenty-two longitudinal sulci; lower portion sparsely incrusted with very fine sand. Disc saucer-shaped. Tentacles,
42, in two rows, the inner row corresponding in position to the marginal teeth, the outer intermediate; sub-equal, conical, pointed, usually radiating horizontally. Coenenchyme band-like, often bearing three polyps abreast, loosely invested with coarse sand.

**Colour.**—Column dull uniform olive, each intersulcus having a blackish spot near its summit; each tooth is silvery white. Disc olive-yellow; tentacles colourless, transparent, with yellow-brown pigment granules.

**Dimensions.**—Column about 3 mm high, and about 2 mm wide.

**Locality.**—Torbay, on rock, between tidemarks.

Hincks (l.c., p. 364) says:—“Mr. Gosse mentions a single colony of this pretty but very minute species as having occurred to him at Broadsands, near Brickham, on sandstone rock. On the opposite side of Torbay, however, and very close to Torquay, I have found it abundantly in the small basins hollowed out in the limestone. The Zoanthus forms little colonies on the floor of these miniature pools; but they may readily be passed over as tufts of some minute weed.” Mr. G. Y. Dixon informs us that he has carefully hunted over the rock where Gosse obtained his original specimens, without being able to re-discover this species.

Fischer (1874, p. 236) describes this species as follows:—“Column covered in its superior half with very fine and agglutinated sand, uniformly brownish or olive, with 22 rays or ridges, on which one sees grains of sand arranged in vertical lines. The superior border of the column is indicated by a dentate border; the teeth are 11 in number, and their colour is white. The disc of the same colour as the column appears rayed. The tentacles to the number of 22 are arranged in two rows; the 11 tentacles of the inner row are longer than the marginal by a third or a fourth. They are conical, transparent, ornamented with some brown spots; their extremities have an opaque white colour. The yellow mouth is not prominent.”

“I have found this species at the landing place of Arcachon, at the limit of low tide; it forms very numerous colonies, which have an appearance of the perforating sponges (Cliona), but their colour is more pronounced. The colony is fixed upon an expansion thickened by sand and other adherent matter. This is perforated by circular holes for the emission of the Zoantheæ, which sink in and disappear when they are disturbed. M. Lafont has met with this species at Guéthary, on rocks.

“The figure given by Mr. Gosse is very bad. . . . The small size, the colour, the habitat of this species, readily distinguish it from the preceding [E. couchii]. When it is extended it measures 4 mm. in diameter.” It occurs between tides (littoral zone), p. 239. The other Papers are merely abstracts.

Later (1887), Fischer gives the following French localities:—“Le Croisic, Piriac (Région armoricaine); Arcachon, Guéthary, (Région aquitanique); Zone littorale,” p. 435.
Jourdan has recently (1890, p. 175) identified a form dredged by the Prince of Monaco (?) either from the Bay of Biscay or off the Azores) as "Palythoa sulcata Gosse."

Zoanthus alderi, Gosse.

Zoanthus alderi:


Zoanthus (Rhyzanthus) alderi:

Andres, 1884, Le Attinie, p. 328.

Form.—"Polyp inversely conical, the summit being two or more times as broad as the base; summit (in the button state) swelling, flat, depressed in the centre, with many (about twenty?) radiating striæ, indicating the marginal teeth. Surface smooth, without any investment of sand, but marked throughout with close-set, transverse, or annular wrinkles. Coenenchyme narrow, smooth, irregularly branching, free from sand."

Colour.—Opaque, milk-white.

Dimensions.—Height of column about two lines (4 mm.); greatest diameter about half a line (1 mm.).

Habitat.—Northumberland; under-surface of a stone, at extreme low water, near the "Bear's Rock," Cullercoats (Alder).

This species has not been met with since its first discovery by J. Alder in 1857. Gosse says: "There were about a dozen polyps in the colony, all of the same size, which seems to be good evidence that they had attained adult dimensions." Alder adds that he has "searched for it several times without success." We cannot help regarding this as an immature form.

No representative of the genus Zoantha, as determined by anatomical investigation, is known to occur in the extra-tropical portion of the North Atlantic.

Until the anatomy of "Z. rubricornis," "Z. sulcatus," and "Z. alderi" is investigated it will be impossible to tell the genus, let alone the species. The same criticism applies to the identification of nearly all the Zoanthæ.
HADDON AND SHACKLETON—A Revision of the British Actiniae.

663

BIBLIOGRAPHY OF THE ZOANTHEÆ.

1767. Ellis, J.:

1786. Ellis, J., and Solander, D.:
The Natural History of many curious and uncommon Zoophytes. London, pls.

1798. Cuvier, G. C. L. D.:

1801. Lamarck, J. B.:

1802. Bosc, L.:

1816. Lamouroux, J. V. F.:
Histoire générale des Polypiers coralligènes flexibles. Caen.

1817. Cuvier, G. C. L. D.:
Règne animale, iv.

1817. Le Sueur, C. A.:

1821. Lamouroux, J. V. F.:
Exposition méthodique des genres de l'ordre des polypiers avec leur description et celle des principales espèces figurées dans 84 planches; les 63 premières appartenant à l'histoire naturelle des Zoophytes d'Ellis et Solander. Paris.

1828. Gray, J. E.:
Spicilegia Zoologica, pls.
1830. Lesson, R. P.:

1832. Delle Chiari, S.:

1833. Quoy et Gaimard:

1834. Ehrenberg, C. G.:

1834. Johnston, G.:

1834. Blainville, H. M. de:

1836. Lamarck, J. B.:
Histoire des Animaux sans Vertèbres. [Deshayes and Milne Edwards’ revised and augmented edition.]

1838. Couch, J.:
A Cornish Fauna, being a Compendium of the Natural History of the County. London.

1842. Johnston, G.:
History of British Sponges and Lithophytes, pls. and woodcuts. Edinburgh.

1843. Thompson, W.:

1844. Thompson, W.:

1844. Forbes, E.:

1845. Landsborough, D.:
1846. Dana, J. D.:

1847. Johnston, G.:
   A History of British Zoophytes, vol. i., vol. ii., pls., 2nd edit. [The one which is always used.]

1847. Døben, M. W., and Koren, J.:
   Om nogle norske Actinier. (Forhandl. Skan. Naturf. Møde, p. 266.)

1848. Døben, M. W., and Koren, J.:
   Ueber einige norwegische Actinien. Isis, p. 536.

1851. Sars, M.:

1851. Le Conte, J. L.:

1856. Thompson, W.:

1856. Steenstrup, J. J. S.:

1857. Milne-Edwards, H.:

1858. Gray, J. E.:
   On the Dysidea papillosa of Dr. Johnston. (Proc. Zool. Soc., 1858, p. 531, pl. x., fig. 8, of separate vol., "Radiata"). [Sidisia borlesi, g. and sp. mm.]

1858. Holdsworth, E. W. H.:

1858. Wright, E. P., and Greene, J. R.:

1858. Gray, J. E.:

1859. Danielssen, D. C.:
1859. HODSWORTH, E. W. H.:

1860. SARS, M.:
Om nogle nye eller lidet bekjendte norske Cælenterater. (Forhandl. Vidensk. Selsk. Christ.)

1860. GOSSE, P. H.:

1860. DUCHASSEING, P., ET MICHELOTTI, J.:

1861. HODSWORTH, E. W. H.:

1861. HINCKS, T.:

1862. ALDER, J.:

1862. SCHMIDT, O.:
Spongien des Adriatischen Meeres. Leipzig, pls.

1864. VERRILL, A. E.:

1866. VERRILL, A. E.:

1866. DUCHASSEING, P., ET MICHELOTTI, J.:
Supplément au Mémoire sur les Coralliaires des Antilles. (Mem. Reale Accad. Sci., Turin (2) xxiii., p. 97, pls.)

1867. BOWERBANK, J. S.:
1867. Gray, J. E.:
Notes on the Zoanthinæ, with Descriptions of some New Genera. (Proc. Zool. Soc., 1867, p. 233, woodcut.) [Brit. sp. referred to—Zoanthus alderi; Sidisia barleei; Epizoanthus, n. g.; E. papillosus; Gemmaria (?) sulcata; Carolia, n. g.; C. couchii.]

1868. Heller, C.:
Die Zoophyten und Echinodermen des Adriatischen Meeres. (Ber. k. zool. bot. Gesellsch., Wien.)

1868. Norman, A. M.:
Last Report on Dredging among the Shetland Isles. (Brit. Assoc. Rep., p. 222.)

1869. Verhille, A. E.:

1872. Dana, J. D.:
Corals and Coral Islands.

1873. Verhille, A. E.:
Report upon the Invertebrate Animals of Vineyard Sound and the Adjacent Waters, with an Account of the Physical Characters of the Region. v., 5, Fauna of the Muddy Bottoms off the open Coast. (Report of the United States Commissioner of Fish and Fisheries, 1873, pp. 295–747, pls. i. to xxxviii.)

1874. Fischer, P.:

1874. Fischer, P.:
Recherches sur les Actinies des côtes océaniques de France. (Nouv. Arch. du Muséum, Paris, x., p. 198.) [The title page of the vol. gives 1874, but Dr. Fischer (1887) and other authors give the date as 1875.]

1874. Smith, S. J., and Harger, O.:

1875. Martens, E. von:

1875. Fischer, P.:
Anthozoaires du département de la Gironde et des côtes du sud-ouest de la France. (Actes Soc. linn. Bordeaux, xxx., p. 188.)

1877. Andres, A.:
1877. **Klunzinger, C. R.**:


1878. **Studee, T.**:


1880. **Koch, G. von**:

Notizen über Korallen. (Morph. Jahrb., vi., p. 355, pl. xvi.)

1880. **Jourdan, E.**:


1882: **Verrill, A. E.**:

Notice of the remarkable Marine Fauna occupying the outer banks of the Southern Coast of New England, No. 3. (Am. Journ. Sci. (3), xxiii., p. 185; *ibid.*, No. 5, p. 300.)

1882. **Hertwig, R.**:


1882. **Marion, A. F.**:


1882. **Verrill, A. E.**:


1884. **Müller, G.**:

Zur Morphologie der Scheidewände bei einigen Palythoa und Zoanthus. Marburg. [Dissertation for Doctor's degree privately printed.]

1884. **Carus, J. V.**:

Prodromus Faunae Mediterraneæ. Stuttgart.

1884. **Andres, A.**:


1884. **Verrill, A. E.**:

1885. VERRILL, A. E.:
Results of the Explorations made by the steamer "Albatross" off the Northern Coast of the United States in 1883. (U. S. Fish. Commission Report for 1883, p. 503, pls.)

1885. PENNINGTON, A. S.:
British Zoophytes: an Introduction to the Hydroidea, Actinoida, and Polyzoa found in Great Britain, Ireland, and the Channel Islands; with plates. London.

1885. EINNOUD, A.:

1885. KOCH, W.:
Neue Anthozoen aus dem Golf von Guinea. Marburg, 36 pp., 5 pls.

1886. RIDLEY, S. O.:

1887. FISCHER, P.:
Contribution à l'Actinologie française. (Arch. Zool. exp. et. gén. (2), v., p. 381.)

1888. HERTWIG, R.:
Supplementary Report. (See 1882.)

1889. HADDON, A. C.:

1889. FISCHER, P.:
Nouvelle contribution à l'Actinologie française: 1re partie, Actinies d'Arcachon; 2e partie, Actinies de Guéthray. (Actes. Soc. linn. Bordeaux, xliii., p. 252.)

1889. MC'LECHR, J. PAYFAIR:

1889. MC'LECHR, J. PAYFAIR:
The Actiniaria of the Bahama Islands, W. I. (Journal of Morphology, iii., p. 1, pls. i.-iv.) [The latter Paper was written before the former, though it was published slightly subsequently to it.]

1890. DANIELSEN, C. C.:
Actinidae. (The Norwegian North Atlantic Expedition, 1876-1878. Zoology. pls.)

1890. BOURNE, G. C.:
Report of a Trawling Cruise in H. M. S. "Research" off the South-West of Ireland. (Journal Marine Biological Association (Plymouth), i., p. 306.)
1890. Jourdan, E.:


1890. Beneden, E. Van:


1891. McMurrich, J. Playfair:


1891. Haddon, A. C., and Shackleton, A. M.:

INDEX OF GENERA AND SPECIES.

CAROLIA = EPIZOAANTHUS, 634.
    couchii, 645.

CORTICIFERA = PALYTHOA.
    lutea, 631.

DYSIDEA = EPIZOAANTHUS, 634.
    papillosa, 634, 636, 645.

ENDEITHOA (? genus).
    rubricomis, 652.

EPIZOAANTHUS, 632, 634.
    abyssomm, 633, 638, 639.
    americanus, 615, 632, 636, 638, 639, 640.
    arenaceus, 619, 632, 637, 639, 649.
    eanrisciosus, 632, 633, 636.
    —— var. linearis, 645.
    elongatus, 633.
    erdmanni, 623, 633, 635, 639.
    eupaguri, 633.
    incrustatus, 615, 616, 618, 622, 627, 632, 634, 635, 636, 639, 648.
    macintoshi, 615, 625, 633, 635, 649, 650, 651.
    norvegicus, 614, 632, 650, 651.
    papillosus, 632, 634, 636.
    parasiticus, 633.
    stellarius, 633.
    thalamophilus, 633.
    wrightii, 614, 615, 616, 633, 635, 651.

GEMMARIA, 630.
    isolata, 621, 627, 630.
    macmurrichi, 614, 616, 617, 630, 643.
    mutuki, 617, 630.
    philippinensis, 630.
    ruci, 621, 626, 627, 630.
    sulcata, 660 (? genus).

ISARUS, 630.
    asymmetricus, 616, 617, 618, 621, 622, 623, 630.
    cliftoni, 630.
    spongiosus, 630.
    tuberculatus, 617, 621, 623, 626, 630.

MAMMILLIFERA, 630, 634.
    auricula, 626, 630.
    conferta, 629 (= Zoanthus confertus).
    incrustata, 636 (= Epizoanthus incrustatus).
    nymphaea, 630.
    tuberculatus, 617, 621, 623 (= Isarus tuberculatus).

MARDCELL = EPIZOAANTHUS.
    erdmanni, 623, 635.

PALYTHOA, 631, 634.
    aggregata, 631.
    anguicoma, 656 (Parazoanthus).
    arenaceus, 636, 645, 649 (= Epizoanthus arenaceus).
    argus, 631.
    axinellae, 617, 654 (Parazoanthus).
    calcarea, 631.
    caribserorum, 631.
    cinerea, 631.
PALYTHOÀ—(continued).

cœsia, 631.
cœsia?, 619, 631.
couchii, 645 (Epizoanthus).
flava, 631.
flavo-viridis, 631.
glaucola, 631.
glutinosa, 631.
howesi, 617, 618, 622, 623, 625, 631.
kochii, 617, 618, 622, 623, 631.
lutea, 631.
mammillosa, 626, 631, 653.
ocellata, 631.
sulcata, 660 (? genus).
tuberculosa, 631.
sp., 656.

PARAZOANTHUS, 633, 653.
anguicoma, 615, 616, 617, 619, 621, 622, 633, 653, 654, 656, 657, 659, 660.
axinellæ, 611, 615, 617, 620, 622, 627, 633, 653, 654, 655, 657.
dichroicus, 615, 617, 619, 622, 625, 633.
douglasii, 615, 617, 619, 624, 625, 633.
hortwigi, 616, 633, 657.
sp., 633.

POLYTHOÀ = PALYTHOÀ (pars), and PARAZOANTHUS (pars), 634.
anguicoma, 656 (Parazoanthus).
arenacea, 636, 645, 649 (= Epizoanthus arenacæus).
axinellæ, 654 (Parazoanthus).
incrastata, 636.
rubricornis, 632 (? genus).
sulcat•, 660 (? genus).

RHYZANTHUS (? genus).
alderi, 662.

SIDISIA = EPIZOANTHUS, 634.
barleei, 632, 634, 636, 638.

SPHENOPUS, 632.
arenacæus, 632.
marsupialis, 626, 632; var. bursiformis, 632.
pedunculatus, 632.

SPONGIA = EPIZOANTHUS, 634.
subcria, 636.

TÆNIOTHOÀ (? genus).
sulcata, 660.

ZOANTHUS, 629, 634.
alderi, 662 (? genus).
anguicoma, 656 (Parazoanthus).
axinellæ, 654 (Parazoanthus).
coppingeri, 616, 618, 621, 622, 623, 629, 643, 657, 660.
confertus, 629.
couchii, 636, 637, 638, 644, 646 (Epi-
zoanthus).
dane (?), 616, 620, 623, 629.
danai, 629.
flos-marinus, 621, 622, 629.
incrastatus, 636, 638 (Epizoanthus).
jukesii, 616, 618, 620, 621, 623, 629.
macgillivrayi, 618, 620, 621, 622, 623, 625, 629, 656.
paguriphilus, 641 (Epizoanthus).
rubricornis, 652 (? genus).
sociatus, 621, 626, 629.
sulcat•, 656, 657, 660 (? genus).
sp., 623, 629.
EXPLANATION OF PLATE LVIII.
PLATE LVIII.

Fig.
1-22. *Epizoanthus incrustatus* (Düb. & Kor.), (p. 636).

1-11. Free variety from Shetland; Mus. Normani—1, simple form, with two polyps; 2-4, 5-8, 9-11, three varietal series.
14-21. Incrusting forms from Galway Bay. These are rather smaller and darker than the more usual forms. This series, starting from a single polyp, illustrates the manner in which new polyps arise.
22. Antero-posterior section of a careinæcium, to show the position of the polyps and the absence of a ventral polyp.

All the above are drawn from spirit specimens, and are natural size.


23-24. Upper and under surface of two different specimens from off S.-W. Ireland; half natural size.
25. Young specimen from W. of Ireland; natural size; *p.p.* posterior polyp.


26. Living specimen from Berehaven; drawn by A. C. H.

29. *Epizoanthus macintoski*, n. sp. (p. 649).

Spirit specimen from Shetland; natural size.


30-32. Living specimens from Dublin Bay; drawn by Mr. G. Y. Dixon; not to scale.
32 showing larvae swimming inside the tentacles.
33. Spirit specimen; natural size.


34. Some of the original type specimens, consisting of one isolated example, and a group of four polyps on a sponge, from Shetland (the specimen has unfortunately dried up); Mus. Normani.
35. Ordinary forms from S.-W. Ireland, on the tube of a Serpula.
36. Button-like variety, on the tube of a Hyalonæcia; both natural size, from spirit specimens.


37. Group of living specimens from S.-W. Ireland; tall variety; drawn by A. C. H.
38. Short variety; spirit specimens all natural size.

[All the above specimens are in the British Museum, excepting Nos. 1-13 and 34. No. 29 was presented by Prof. W. C. M'Intosh, and No. 33 by Mr. G. Y. Dixon.]
EXPLANATION OF PLATE LIX.
PLATE LIX.

LETTERING ADOPTED IN THE FIGURES.

eu., . . . cuticle.
et., . . . ectoderm.
et. can., . . . ectodermal canal.
eut. sin., . . . encircling sinus.
end., . . . endoderm.
end. can., . . . endodermal canal.
f., . . . fibrilla.
incr., . . . incrustation.
m., . . . mesoglea.
mes., . . . mesentery.
nem., . . . nematocyst.
p. b. m., . . . parieto-basilar muscle.

Fig.
1. *Epizoanthus macintoshi*, n. sp. (p. 649). Transverse section through the body-wall, $\frac{2}{B}$. *

2. *Epizoanthus incrustatus* (Düb. & Kor.), (p. 636). Transverse section through the body-wall, $\frac{2}{B}$.

3. *Epizoanthus wrightii*, n. sp. (p. 651). Transverse section through the body-wall, $\frac{2}{B}$.

4. *Epizoanthus couchii* (Johnst.), (p. 644). Transverse section through the body-wall, $\frac{2}{B}$.

5. *Epizoanthus norvegicus* (Kor. & Dan.), (p. 650). Transverse section through the body-wall, $\frac{2}{B}$.


7. *Epizoanthus arenaceus* (D. Ch.), (p. 649). Transverse section through the body-wall, $\frac{2}{B}$.

8. *Parazoanthus axinella* (Schmidt), (p. 654). Transverse section through the body-wall, $\frac{2}{B}$.


10. *Parazoanthus dixoni*. Transverse section through the body-wall, $\frac{2}{B}$.

11. *Parazoanthus anguiicoma* (Norm.), (p. 656). Transverse section through the body-wall, $\frac{2}{B}$.

12. *Parazoanthus anguiicoma*. Vertical section through the body-wall, $\frac{2}{B}$.

* These letters of magnification refer in all cases to Zeiss' system.
EXPLANATION OF PLATE LX.
PLATE LX.

LETTERING ADOPTED IN THE FIGURES.

cut., . . . . cuticle.
ee., . . . . ectoderm.
euc. sin., . . . . encircling sinus.
end., . . . . endoderm.
end. sph. m., . . . . endodermal sphincter muscle.
incr., . . . . incrustation.
m., . . . . mesogloea.
m. en. mes., . . . . macroenemic mesentery (the sulco-sulcar lateral mesentery).
m. f., . . . . mesenterial filament.
m. sph. m., . . . . mesogloval sphincter muscle.

nem., . . . . nematocyst.
ex., . . . . oesophagus.
ax. r., . . . . oesophageal ridge.
p. b. m., . . . . parieto-basilar muscle.
r. eot., . . . . reflected ectoderm.
r. end., . . . . reflected endoderm.
r. m., . . . . retractor muscle.
s. d., . . . . sulcal directive mesenteries.
s. d., . . . . sulcal directive mesenteries.
s. gr., . . . . sulcal groove.
sp. . . . . sperm-cell (testis).

Fig.

1. *Epizoanthus inerustatus* (Düb. & Kor.), p. 636. Transverse section through the oesophageal region of the column, \( \frac{4}{a^8} \frac{10}{10} \).

2. *Epizoanthus wrightii*, n. sp. (p. 651). Vertical section through the sphincter muscle, \( \frac{2}{B} \).

3. *Epizoanthus conchii* (Johnst.), (p. 644). Vertical section through the sphincter muscle, \( \frac{2}{B} \).

4. *Epizoanthus arenaceus* (D. Ch.), (p. 649). Vertical section through the sphincter muscle, \( \frac{2}{B} \).

5. *Epizoanthus pagurophilus*, Verr. (p. 641). Transverse section through a fertile mesentery, \( \frac{4}{a^8} \frac{10}{10} \).

6. *Parazoanthus axinella* (Schmidt), (p. 654). Transverse section through the oesophageal region of the column, \( \frac{4}{a^8} \frac{10}{10} \).

7. *Parazoanthus axinella*. Transverse section through a fertile mesentery, \( \frac{2}{B} \).

8. *Parazoanthus dixoni*, n. sp. (p. 658). Vertical section through the sphincter muscle, \( \frac{2}{B} \).

9. *Parazoanthus dixoni*. Transverse section through a perfect and an imperfect mesentery, \( \frac{2}{B} \).

* These letters of magnification refer in all cases to Zeiss' system.
TRANSACTIONS (NEW SERIES).

VOLUME I.
Parts 1-25.—November, 1877, to September, 1883. (Part 25 contains Title-page to Volume.)

VOLUME II.
Parts 1-2.—August, 1879, to April, 1882. (Part 2 contains Title-page to Volume.)

VOLUME III.
Parts 1-14.—September, 1883, to November, 1887. (Part 14 contains Title-page and Contents to Volume, also Cancel Page to Part 13.)

VOLUME IV.

3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.
5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.
7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleostean. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.
12. A Revision of the British Actiniae. Part II. : The Zoanthæ. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and Miss Alice M. Shackleton, B.A. Plates LVIII., LIX., LX. (November, 1891.) 3s. 6d.
THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

XIII.

REPORTS ON THE ZOOLOGICAL COLLECTIONS MADE IN TORRES STRAITS

BY PROFESSOR A. C. HADDON, 1888-1889.

ACTINLÆ. I. ZOANTHÆÆ. BY PROFESSOR ALFRED C. HADDON, M.A.
(Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and
MISS ALICE M. SHACKLETON, B.A. Plates LXI., LXII. LXIII., LXIV.

DUBLIN:

PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

LONDON: WILLIAMS AND NORRIGATE.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.

1891.

Price Three Shillings.
[December, 1891.]

THE

SCIENTIFIC TRANSACTIONS

OF THE

ROYAL DUBLIN SOCIETY.

VOLUME IV. (SERIES II.)

XIII.

REPORTS ON THE ZOOLOGICAL COLLECTIONS MADE IN TORRES STRAITS

BY PROFESSOR A. C. HADDON, 1888-1889.

ACTINÆ. I. ZOANTHEÆ. BY PROFESSOR ALFRED C. HADDON, M.A.
(Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and
MISS ALICE M. SHACKLETON, B.A. Plates LXI., LXII. LXIII., LXIV.

DUBLIN:

PUBLISHED BY THE ROYAL DUBLIN SOCIETY.

LONDON: WILLIAMS AND NORGATE.

PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.

1891.
The following is the first instalment of an investigation on the structure and systematic relations of the Actiniae collected by one of us in Torres Straits. We decided to publish our account of the Zoanthæ first, as it is a well circumscribed group and admits of independent treatment. We took this opportunity of studying the British forms, and have thus had a considerable number of forms under examination at the same time. This has given us a personal knowledge of every genus except Mammilifera, of which genus no authentic specimens exist in any museum.

Our account of the British Zoanthæ is simultaneously published with this as "A Revision of the British Actiniae;" Part II.: The Zoanthæ (Trans. Royal Dublin Society, vol. iv., ser. ii.); and we would refer the reader to that Memoir for a general summary of the anatomy of the group, and a special account of that of the British representatives. We have also given a classification of the Zoanthæ, and as far as is possible have allocated all the species described by other authors to their proper genera. It is impossible at the present time to monograph this group, as there is such a general sameness in external character that it makes it difficult to seize on points which are of descriptive value. The present confusion in which this group lies is mainly due to this fact; the fault is that of the animals themselves rather than that of the zoologists who have described and named them. This similarity of appearance not only affects the species of a genus, but also the species of different genera. Thus it becomes a necessity for every species to be examined anatomically by means of microscopical sections, first to determine its genus, and secondly to discover accurate specific characters. Once a species is thoroughly
known it will generally be possible to identify other specimens belonging to that species by external characters only. Owing to the incrusted nature of most of the Zoanthæ it is very difficult to get satisfactory sections, and for the same reason spirit specimens are often apt to be badly preserved for histological purposes.

It is not unfair to point out that the disorder which has occurred in this group is also partially due to the fact that many zoologists have not paid due regard to the generally recognised rules of zoological nomenclature, and have not taken the trouble to thrash out the synonymy; and some have identified certain forms with pre-existing species in a rather reckless manner.

Owing to the lack of salient external characters, which could be observed in preserved specimens, we have not been able to give diagnostic names to most of the species, and we have consequently associated them with the names of zoologists who have collected in Torres Straits, or who have studied the group. The types of the species have been given to the British Museum, in which institution will also be found a complete set of slides illustrating the anatomy of all the forms described in this and in the preceding Memoir.

CLASSIFICATION OF THE GROUP.
ZOANTHÆ.

Actiniae 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 occur 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 sulcar are the oldest, and the sulcar the youngest. Only the perfect mesenteries are fertile, or bear mesenterial filaments. A single sulcar œosphageal groove is present; the mesogloea 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 coœnenchyme, the coelenteron of each polyp communicating with that of the other members of the colony by means of basal endodermal canals.
Family. *Zoanthidae*, Dana, 1846.

(With the definition of the group.)


Zoanthae in which the sulcar element of the primitive sulco-lateral pair of mesenteries (cnemes) is imperfect:—

**Genera of the Brachycnemini.**

<table>
<thead>
<tr>
<th>Genus</th>
<th>Author</th>
<th>Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Zoanthus</em></td>
<td>Lamarck, 1801</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Isaurus</em></td>
<td>Gray, 1828</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>(? Mammillifera)</em></td>
<td>Lesueur, 1817</td>
<td></td>
<td>(Not represented in Torres Straits.)</td>
</tr>
<tr>
<td><em>Gemmaria</em></td>
<td>Duchassaing et Michelotti, 1860</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Palythoa</em></td>
<td>Lamouroux, 1816</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Sphenopus</em></td>
<td>Steenstrup, 1856</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Zoanthae in which the sulcar element of the primitive sulco-lateral pair of mesenteries (cnemes) is perfect:—

**Genera of the Macrocnemini.**

<table>
<thead>
<tr>
<th>Genus</th>
<th>Author</th>
<th>Year</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Epizoanthus</em></td>
<td>Gray, 1867</td>
<td></td>
<td>(Not represented in Torres Straits.)</td>
</tr>
<tr>
<td><em>Parazoanthus</em></td>
<td>Haddon &amp; Shackleton, 1891</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sub-family. *Brachycnemini*.

**Zoanthus**, Lamarck, 1801.

*Zoanthus*, Cuvier, 1817.

*Zoanthus* (*Rhyzanthus*), Andres, 1884.

Brachycnemic Zoanthae with a double mesoglocaal sphincter muscle. The body-wall is unincrusted; the ectoderm is usually discontinuous; a well developed ectodermal canal system in the mesogloea. Dioecious or monoecious. Polyps connected by a thin coenenchyme.
Cuvier (1798) was the first to recognise some distinction between the Zoantheae and other Actinia, but in an indefinite sort of way; he refers to "1. Le zoanthe à cinq pétales (Actin. dianthus); 2. Le zoanthe à drageons (Actin. sociata)."

Lamareck (Système, 1801) first divided the Actinæ into the genera Actinia and Zoantha; he says (1801, p. 363): "1. genre. Zoanthe, Zoantha—Zoantha sociata, Act. sociata, Sol. et Ellis, Hydra sociata, Gmel."

Bosc (1802, p. 261) refers to "Zoanthe, Zoantha, Lam.; Z. ellisii; Hydra sociata; Act. sociata, S. & Ell."

Cuvier, in 1817 (p. 53), speaks of Zoanthus sociatus.


Dana is the only later author who adheres to Zoantha instead of Zoanthus. According to the generally accepted rules of zoological nomenclature the Greek avdos would have to be written anthus, it being agreed that, "in writing zoological names, the rules of Latin orthography must be adhered to."

TORRES STRAITS SPECIES OF THE GENUS ZOANTHUS.

Z. coppingeri, n. sp.
Z. jukesii, n. sp.
Z. macgillivrayi, n. sp.

Zoanthus coppingeri, n. sp.

(Pl. lxI., figs. 1, 2; Pl. lxIII., fig. 1; Pl. lxIV., figs. 1-4.)

Form.—Body smooth, pyriform when contracted, rather elongated when expanded. Polyps in clusters, the buds springing from the bases of the polyps themselves; coenenchyme, thin, encrusting. Tentacles, in two rows, similar.

Colour.—Pinkish below, greenish or bright green above, sometimes entirely pinkish; always with brown streak-like spots; disc, burnt sienna, with darker spots; rim of mouth, brown; tentacles, gray, with a single row of black spots; there is a black spot between each tentacle, and these are continued as black lines on the capitulum.

Dimensions.—Length of a contracted specimen, 15 mm.; diameter of upper portion, 5 mm.

We have named this species in honour of Dr. Coppinger, who, when surgeon on board H.M.S. "Alert," collected some marine zoological specimens from Torres Straits.*

**Body-wall** (Pls. lxil., lxiv.).—The wall of the column is bounded externally by a distinct cuticle. Between this cuticle and the ectoderm lies a thin peripheral layer of mesogloea, the "subeuticula" of Andres and M'Murrich. The ectoderm forms an almost continuous layer, but is crossed by numerous delicate strands of mesogloea, which unite to form the peripheral layer. In addition to the ordinary columnar cells, nematocysts of an oval shape are present. Numerous branching and anastomosing canals arise from the ectoderm, and run through the mesogloea, generally in a radial direction. They vary greatly in size. Sometimes they run along close to the endoderm, but we have never observed any connexion with it. Many of these canals pass into the mesenteries, where they form large sinuses. Nematocysts, similar to those in the ectoderm, are found in these canals. The mesogloea, which constitutes the chief thickness of the body-wall, is homogeneous and clear, and is permeated by the usual minute cells, which are drawn into fine protoplasmic strands. These have a radial direction, and extend right across the mesogloea, from endoderm to ectoderm. The endoderm is crowded with zooxanthellae. There is a slight diffuse endodermal muscle.

**Capitulum.**—The ectoderm becomes continuous in the capitulum, and in contracted specimens is thrown into deep folds. Nematocysts are very numerous.

**Sphincter muscle.**—The double sphincter muscle is a powerful one, the upper portion being slightly shorter than the lower one (Pl. lxiv., fig. 3). It consists of numerous irregularly shaped cavities, the mesogloea being arranged in complicated plaitings.

**Tentacles** (Pl. lxiv., fig. 2).—The ectoderm of the tentacles is normal and ciliated. The nuclei form a distinct central band in section. Outside the band are numerous, small, thin nematocysts, whilst between the band of nuclei and the mesogloea small irregular cells may be discerned, which are probably nerve cells. There is a diffuse ectodermal muscular layer. The fibres, which are longitudinal in direction, are supported on simple plaitings of mesogloea. The mesogloea forms a thin layer without canals or enclosures of cells. The endoderm, which is crowded with zooxanthellae, is very thick, so that the lumen of the tentacles is almost obliterated. Nematocysts, similar to those found in the capitulum and other parts of the ectoderm, are abundant in the endoderm of the tentacles. The endodermal muscle fibres are circular in direction.

* See "Report on the Zoological Collections made in the Indo-Pacific Ocean during the Voyage of H. M. S. 'Alert,' 1881–1883" (1884).
Disc.—The structure of the disc is very similar to that of the tentacles, but we have not found nematocysts in the endoderm of this region.

Esophagus.—The ectoderm of the oesophagus forms a simple layer. The groove is visible, although not very well marked. The mesogloea is extremely thin, and of uniform thickness.

Mesenteries.—The arrangement of the mesenteries is brachyenchyme. They are coiled and folded, almost entirely filling up the body-cavity. The ectoderm of the oesophagus is reflected upwards and continued downwards into the mesenterial filaments, forming numerous folds along each mesentery (Pl. lxiv., fig. 4), in a manner which will be more fully described in our account of Z. macgillivrayi. The mesogloea is extremely thin in the upper part of the mesentery, although thicker in the immediate neighbourhood of the wall, where it usually contains a "basal" canal. Lower down the mesogloea is thicker throughout, and here the canal expands to form the large sinus, which, as we have previously mentioned, is connected with the ectodermal canal system of the body-wall (Pl. lxii., fig. 1). The endoderm of the mesenteries forms a deeper layer than that of the body-wall, and zooxanthellae, though present, are not nearly so numerous. The nuclei of the columnar cells form a peripheral band, leaving a clear space next to the mesogloea. Nematocysts are also to be found in the endoderm of this region. The parieto-basilar muscle is diffuse and feebly developed. The longitudinal muscle fibres are also very feeble, being scarcely discernible. There is no special thickening of the endoderm in the lower part of the mesenterial filaments as in Z. macgillivrayi.

Gonads.—The sexes are distinct. We have sections of both male and female specimens (Pl. lxiv., figs. 3, 4). The gonads appear to be distributed on the mesenteries in irregular rows.

Zoanthus jukesii, n. sp.

(Pl. lxi., figs. 3-5; Pl. lxii., fig. 2; Pl. lxiii., fig. 1.)

Form.—Body short and thick; body-wall smooth and delicate; coenenchyme forming stolons: tentacles in two cycles of about 20–24 in each.

Colour.—Body and stolon translucent gray, the endoderm shining through with a brown tint (owing to the presence of zooxanthellae); capitulum pink, with 24 dark lines; disc brown, with, usually, pairs of pale lines (mesenteries) for inner cycle of tentacles; mouth with greenish lip; oesophagus gray. Tentacles: inner cycle green, with dark rings or marks on the oral aspect; outer cycle opaque pale pink; all the tentacles with a dark spot at the tip; the base of the tentacles of the outer cycle is in some specimens tinged with green.
Dimensions.—Height 7–12 mm.; diameter of disc, 6 mm.

Locality.—Fringing Reef, Mer (Murray Islands), Jan. 29, 1889. Numerous specimens.

We associate this species with the name of the late Prof. Beete Jukes, at one time Professor of Geology in the Royal College of Science, Dublin, who was also the author of the interesting Voyage of the "Fly."* To this day the name of this genial naturalist is still remembered in the Murray Islands and in Erub.

Body-wall (Pl. lxii., fig. 2).—A cuticle and peripheral mesogloea are present as in Z. coppingeri. The cells of the ectoderm are not distinct but appear to have become fused, as in the specimen of Z. sociatus, described by M'Murrich (1889, p. 63). For the most part they appear to form a quite continuous and narrow layer, but in some parts the contents of the cells, adhering closely to the mesogloea on either side, leave an empty space, across which, irregularly placed and exceedingly delicate strands of mesogloea are seen to pass. Anastomosing canals, connected with the ectoderm, are present, though not at all so numerous as in Z. coppingeri. Lacunae, clearly of similar origin, but completely surrounded by the mesogloea, are more frequently to be met with. The canals and lacunae are most abundant in the lower part of the column, and here their connexion with the basal canals of the mesenteries can be demonstrated (Pl. lxii., fig. 2). The mesogloea is of the usual character. Zooxanthellae also abound in the endoderm of this species. There is a diffuse endodermal muscular layer, supported by acute mesogleal prominences.

Capitulum.—The ectoderm of the capitulum is thrown into folds, as in Z. coppingeri, and rather opaque oval cells, with a clear outline (probably nematocysts, are here very numerous, being generally embedded singly in the mesogloea.

Sphincter muscle.—The sphincter muscle is not so strongly developed as in Z. coppingeri. Of the two parts of the muscle the upper one is in this case the longer. The muscle cavities are larger and less filled up with cells, the plaitings of the mesogloea being simpler than in Z. coppingeri.

Disc and tentacles.—The ectoderm of the disc and tentacles closely resembles that described for Z. coppingeri. The endoderm is crowded with zooxanthellae, but contains no nematocysts.

The ectoderm of the oesophagus is thrown into slight folds. The groove is well marked (Pl. lxiii., fig. 1).

Mesenteries (Pl. lxiii., fig. 1).—The arrangement of the mesenteries is of the usual brachyenchyme type. The reflected ectoderm of the oesophagus forms a smaller

number of folds than in the last species described. The mesenterial filaments also appear shorter in transverse section. The mesogloea is thicker throughout, and usually contains more than one canal in each mesentery.

These canals appear to run from the base of the mesenteries to the oesophageal region. Near the base they appear to be connected with ectodermal spaces in the body-wall. The endoderm of the mesenteries is very similar to that of the body-wall.

The longitudinal muscles are better developed than in Z. coppingeri, the mesogloea being thrown into slight plaitings to support the fibres. The parieto-basal fibres, though distinct, are rarely supported by plaitings.

Gonads.—The sexes appear to be distinct in this species also. All the specimens examined by us containing mature reproductive organs were female. The gonads are irregularly arranged as in Z. coppingeri.

This species somewhat resembles the preceding one; spirit specimens can be distinguished externally by the following characters:—Z. coppingeri is larger; markedly pyriform when contracted, and the brown spots persist (for at least three years).

Zoanthus macgillivrayi, n. sp.

(Pl. lxi., fig. 6; Pl. lxii., fig. 3; Pl. lxiii., fig. 2; Pl. lxiv., figs. 5–8).

Form.—Body smooth, transversely wrinkled, with a thick cuticle, upper part of column slightly swollen, disc large; tentacles small, 32 in number, in two cycles; mouth very small. The capitulum in expanded specimens exhibits two encircling grooves, which indicate the double sphincter muscle, coenenchyme forming a flattened stolon.

Colour.—Not determined when alive; yellowish in alcohol.

Dimensions.—Height of large specimens, 18 mm.; average diameter of colour, 3 mm.; diameter of disc, 6.5 mm.

Locality.—Fringing reef, Mabuiag, Sept. 21, 1888. Six specimens.

We acknowledge in the specific name we have given to this species the zoological labours in Australasia of the late J. Macgillivray, author of the valuable "Voyage of the Rattlesnake."*

Body-wall.—The wall of the upper part of the column is comparatively thin. Lower down it is much thicker. The cuticle is thick, and foreign bodies,

* Narrative of the Voyage of H. M. S. "Rattlesnake," commanded by the late Captain Owen Stanley, R.N., F.R.S., during the years 1846–1850 (1852).
foraminifera, diatoms, &c., are occasionally to be found embedded in it, and in the peripheral layer of mesogloea. The latter can be very distinctly seen in this species. As in Z. jukesii the cells of the ectoderm appear to have become fused, and crossing strands of mesogloea can only be seen in those few places where the ectodermal space is nearly empty. Anastomosing ectodermal canals, very similar to those found in Z. coppingeri, run through the mesogloea and are connected with the basal canals of the mesenteries near the union of the column with the coenenchyme (Pl. lxii., fig. 3). The surface of the column is thrown into numerous folds, which appear in cross-section as deep ectodermal bays lined with cuticle.

Sphincter muscle.—The sphincter muscle is somewhat similar to that in Z. jukesii, the upper being the longer of the two parts (Pl. lxiv., fig. 5). The cavities are simpler than in Z. coppingeri, but they are not so large as in Z. jukesii.

Disc and tentacles.—The structure of the disc and tentacles is very similar to that of the preceding species. There are no nematocysts in the endoderm.

Oesophagus.—There is a well marked oesophageal groove.

Mesenteries.—Of the two specimens which we have cut transversely, one shows the usual brachycenemic arrangements. In the other there are four imperfect mesenteries at the sulcular side of the oesophagus, instead of the usual pair of imperfect directives. The reflected oesophageal ectoderm and the structure of the mesenterial filaments can be well studied in this species. As can be seen in a longitudinal section, such as that figured (Pl. lxiv., fig. 5), the ectoderm of the oesophagus passes continuously on to the mesentery, where it suddenly becomes greatly thickened, and is thrown into transverse folds, the whole thickening having a crescentic form, first curving upwards and then downwards, losing itself, in the mesenterial filament. The ectoderm is reflected on both sides of every one of the perfect mesenteries, presenting in transverse section a characteristic pinnate appearance (Pl. lxiv., fig. 6). As above mentioned, the reflected ectoderm passes gradually into the mesenterial filament, the characteristic V shape of the latter (Pl. lxiv., fig. 7) being continuous with the peripheral folds of the former. The lateral elements of the mesenterial filaments gradually become shorter, so that as it descends only the median portion is left. Numerous nematocysts are found in this lower portion of the filament (Pl. lxiv., fig. 8). In this species the mesenterial filaments are confined to the upper part of the column, gradually disappearing about the middle of the column. As the filaments disappear the mesenteries also become much narrower (appearing in transverse section to shorten), projecting but a little way into the coelenteron (Pl. lxiii., fig. 2). Lower down they again widen and project further, finally uniting in the centre at the base of the polyps to form the coelenteric canals of the stolon (Pl. lxii., fig. 3). The mesogloea of the mesenteries is well developed, especially near the base.
Canals are present from the oesophageal region downwards, frequently two or three in the perfect mesenteries. These canals are connected with the canals of the body-wall at the base of the column. Nematocysts are numerous in the endoderm of the mesenteries. The longitudinal muscle fibres form a simple layer, the parieto-basal muscles are better developed and supported upon slightly branched plaits of mesogloea.

**Gonads.**—No gonads were present in the specimens we examined.

This species cannot be mistaken for either of the two previously described.

**ISaurus**, Gray, 1828.

**Antinedia**, Duch. & Mich., 1866.

**Polythoa (Monothoa) (pars)**, Andres, 1884.

**Zoanthus (Monanthus) (pars)**, Andres, 1884.

Large brachycnemic Zoanthæ with a single mesogloeaal sphincter muscle. The body-wall is unincrusted; the ectoderm discontinuous; ectodermal and endodermal bays and small canals in the mesogloea. Monoecious or dioecious. Polyps in small clusters or solitary.

The genus Isaurus was established by J. E. Gray in 1828 (Spic. Zool., 1828, p. 8) to include a species not before described, specimens of which from an unknown locality were in the British Museum. He named this species *Isaurus tuberculatus* on account of the tubercles on its surface. The name Isaurus is a Latinized version of Isaure, a name applied by Savigny (Description de l'Egypte, Polypes, pl. 2, figs. 1–4, 1811, ined.) to four species figured by him in 1811, and supposed by Gray to be of the same genus as his *I. tuberculatus*. Savigny published, however, neither the characters of the genus nor descriptions of the species. Lamouroux mentions the genus as Isaura, but neither does he define it in any way.

The genus Isaurus must therefore be regarded as Gray’s, and *Isaurus tuberculatus* as the type species.

In 1860 Duchassaing and Michelotti found specimens at St. Thomas and Guadaloupe, which closely agreed with Gray’s account of *Isaurus tuberculatus*. Although unaware of the existence of Gray’s species, they gave to their specimens the same specific name, calling them *Zoanthus tuberculatus*, and subsequently in 1864 (forming for the species a new genus), *Antinedia tuberculata*. Andres considered that Gray’s *I. tuberculatus*, and Duchassaing and Michelotti’s *A. tuberculata*, were distinct species, and consequently renamed the latter *A. duchassaingi*. 
In 1889 McMurrich described specimens from the Bermudas, evidently belonging to Gray's species and also agreeing closely with *A. tuberculata*, Duch. & Mich., which he considers to be identical with it. Anatomical examination of these specimens showed that they possessed most of the characters which Erdmann has ascribed to the genus Mammillifera. McMurrich therefore identified his specimens as *Mammillifera tuberculata* (Gray).

From Erdmann's Paper, however, we cannot find that he has sufficient reasons for concluding that the characters attributed by him to Mammillifera are possessed by any of the species for which that genus was erected by Lesueur in 1817. The specimens found by Erdmann in the museum at Bonn, from which he deduced these generic characters, were not referred to any species.

The generic name Mammillifera was adopted in 1817 by Lesueur for two species from the West Indies, named by him *M. auricula* and *M. nymphaea*. His definition of the genus is "A large cuticular expansion serving as a base for numerous animals, which, when contracted, assume the form of mammae" (p. 178). From the dimensions given by Erdmann for his unnamed specimen, it seems possible that it agrees to some extent with this description, but the same might be said of *Zoanthus jukesii*; whilst both Gray's *I. tuberculatus* and our *I. asymmetricus* entirely disagree with it in outward form. It therefore appears that it is impossible to determine the true characters of the genus Mammillifera until the type species *M. auricula* has been recovered and submitted to anatomical examination. Until this is done we must therefore retain the name Isaurus for those species which undoubtedly belong to the same genus as *I. tuberculatus* and *I. asymmetricus*.

Although, as above stated, Gray instituted the genus Isaurus for *I. tuberculatus*, we find that in 1867 (P. Z. S., p. 234) he erects a new genus, Pales, for a closely allied form. In his "Solitary, rarely irregularly aggregate" division of the "Zoanthi malacodermi, or soft-skinned Zoanthi, or Zoanthinæ," he recognises three genera: "Isaurus, Gray, Spic. Zool., 8, 1825 [the copy we have seen is dated 1828]? Orinia, Duchassaing and Michelotti, Mém. Coral. des Antilles, 54. Pales [which he defines thus]—Body cylindrical, isolated, solitary, clustered, or sometimes proliferous, but each specimen having a separate base; outer skin smooth, thin, olive-brown, slightly concentrically wrinkled; the tentacles numerous, the internal laminae numerous, slender, only slightly elevated, straight and parallel above, with a thickened edge, and sinuous below. *Pales cliftoni* (fig. 1, p. 236)—Hab. Western Australia (Mr. Clifton). The bodies are from ½ to ¾ inch in diameter; but they vary greatly in length, some being as much as 2 inches long; but the general length [in spirits] seems to be about an inch. . . . They are found attached to shells, both isolated and in clusters, and the larger ones are attached to the base of each other, forming a somewhat stellate cluster, as if they were free, floating in the sea."

5 F 2
It seems probable that the two genera are coterminous, and, if so, *I. cliftoni* will rank as a second Australian species of *Isaurus*.

In 1877 Andres described (p. 226) a new genus and species, *Panceria spongiosa* from Port Natal; but in 1884 (p. 315) he abandoned the genus, and re-named it *Polythoa (Monothoa) spongiosa*. We regard this as belonging to the genus under discussion.

**TORRES STRAITS SPECIES OF THE GENUS *ISAURUS*.**

*I. asymmetricus*, n. sp.

*Iaurus asymmetricus*, n. sp.

(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, in retracted specimens, with usually four rather irregular longitudinal rows of tubercles, arranged in such a manner that there is a longitudinal area free from them. In some specimens there are intermediate tubercles, which may even form one or two rows. Young specimens are entirely smooth. The smooth side is somewhat shorter than the tuberculated, so that the body bends over to the former, and the introverted mouth is rarely terminal. The contracted capitulum exhibits radiating furrows from 18 in number upwards.

The polyps grow either singly or in small clusters. In the latter case there is a common, firm, fleshy, incrusting coenenchyme, occasionally forming stolons, from which new buds arise.

**Colour.**—Whitish below, passing into brownish above; the darker portion is variously mottled with cream, or greenish cream, and occasionally diversified with darker spots; the tubercles are somewhat pinkish in colour.

**Dimensions.**—Average size of retracted specimens, 45 mm. in length; greatest diameter, 7 mm. The longest specimen measured 56 mm. in length when retracted.

**Locality.**—Torres Straits; on fringing reef between tides. Mabuiag, Oct., 1888, numerous specimens; 15–20 fathoms, between reefs, Murray Islands, Jan. 5, 1889, two specimens.

The specific name is derived from the marked asymmetry of the polyp. It is undoubtedly nearly allied to the *Mammillifera tuberculata* of McMurrich (1889, p. 117). 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.
Our deeper water specimen was shorter and relatively much more tuberculated. In the "Special volume of the Proceedings of the Geographical Society of Australasia" (Sydney, 1885), under a section designated as "New Guinea Exploration," there is a letter from Dr. J. W. Haacke, concerning a collection of Anthozoa from Thursday Island, Torres Straits, in which he refers to "a species belonging probably to a new genus closely allied to the genera Polythoa and Zoanthus. This genus would be characterized by showing, even externally, a very obvious bilateral symmetry, better, I believe, than any other Anthozoon" (p. 225). There is no doubt that this is our new species.

We have copied Gray's account of the other Australian representative in our account of the genus, the absence of tubercles readily distinguishes it from our species. The same also holds good for the Port Natal species, *I. spongiosa*.

Body-wall (Pl. lxii., fig. 4).—The thick body-wall is covered by a cuticle as in the species of Zoanthus described. The ectoderm is not continuous, but is broken up into fairly uniform groups of cells by well developed strands of mesogloea, which connect the peripheral with the general mesogloea (Pl. lxiii., fig. 6). Amongst the ordinary columnar cells of the ectoderm are to be found numerous zooxanthellae, as well as occasional large nematocysts. Bays of ectoderm, in which the cuticle may to a greater or less extent be involved, often occur. Canals and lacunae of much smaller diameter than the anastomising canals which occur in the species of Zoanthus we have described, are also present. Some of these can be shown to be continuous with the ectoderm, whilst others have an equally clear connexion with the endoderm (Pl. lxiii., fig. 5). Endodermal bays, which may be quite shallow, or may extend to a greater or less extent into the mesogloea as large open canals, are not unfrequent (Pl. lxii., fig. 4; Pl. lxiv., fig. 9). Occasionally these are slightly branched. A few nematocysts, smaller than those found in the ectoderm, as well as zooxanthellae, are present in the endoderm. The endodermal muscular layer is well developed.

Sphincter muscle.—The single mesogloea sphincter muscle is extremely thick and powerful. The cavities are well filled with muscle cells (Pl. lxiii., fig. 4).

Capitulum.—The cuticle and peripheral layer of mesogloea, as well as the strands of mesogloea which break up the ectoderm, are present in that part of the capitulum, which in contracted specimens is thrown into folds, but the cuticle disappears, and the ectoderm becomes continuous as the tentacles are approached.

Disc and tentacles.—The usual small nematocysts are found in the outer part of the ectoderm of the tentacles. The nuclei do not form a distinct central band, but are diffused, leaving, however, a clear band next to the muscle fibres. The ectodermal muscular layer is remarkably well developed. The fibres are supported on fine and complicated mesogloea plaitings, forming in some cases a band nearly equal to one-third of the entire thickness of the wall of the tentacle.
In some places these plaitings appear to unite to form a distinct band of mesogloea, outside the muscle fibres, so that here the muscle may be regarded as mesogloea. The endodermal muscular layer is well developed, especially at the bases of the mesenteries, but it is not at all so remarkable as is that of the ectoderm. The endoderm, as well as mesogloea, is relatively thin in the tentacles. The endoderm contains numerous zooxanthellae.

_Sesophagus._—The ectoderm of the _œsophagus_ is thrown into slight and irregular folds. The groove is only indicated by a slight depression in the region of the sulcar directives. Both mesogloea and endoderm form very thin layers. Nematocysts are present in the endoderm similar to those found in the endoderm of the mesenteries and column in this region.

_Mesenteries._—The arrangement of the mesenteries is brachycnemic. The imperfect mesenteries are well developed, sometimes extending about half way from the body-wall to the _œsophagus_ (Pl. _lxiv._, fig. 9). The ectoderm of the _œsophagus_ is reflected a short way above the lower opening of the _œsophagus_, and forms the mesenterial filaments in the usual way. The mesogloea of the mesenteries is comparatively well developed even in the _œsophageal_ region, but it becomes much thicker as it descends. Several canals run vertically through each mesentery. Some of those appear to be connected in the coenenchyme with the endoderm (Pl. _lxiii._, fig. 5). It is possible that others are connected with ectodermal canals or lacunae, but we have not been able to trace any to the ectoderm. The endoderm of the mesenteries is very similar to that of the body-wall. It contains numerous small oval nematocysts. The muscles are fairly well developed. The mesogloea on each side of the mesentery, close to the body-wall, is thrown into numerous and often branching plaits, which support the fibres of the parieto-basilar muscle (Pl. _lxiv._, fig. 9). On one side of each mesentery the mesogloea is thrown into very slight plaits all the way up. These plaits support the longitudinal fibres. On the other side, the parieto-basilar fibres (cut obliquely in transverse section) extend considerably beyond the mesogloea plaits. In the imperfect mesenteries the mesogloea plaits extend the whole way on both sides, and it is hardly possible to distinguish two distinct sets of fibres.

_Gonads._—In only one of our specimens did we find gonads. These were all female; but they were few and not fully developed. We cannot say with certainty whether this species is monoecious or dioecious, though our evidence leads us to suppose it to be the latter.


Solitary brachycnemic Zoanthæ with mesogloea sphincter muscle. The body-wall is incrusted with grains of sand and spicules. The ectoderm is usually
discontinuous, but may be continuous. Lacunæ and cell-islets are found in the mesogloea. Disscous.

This genus was recovered by McMurrich (1889), who identified a Zoanthid from the Bermudas as Gemmaria rusei, Duch. & Mich. (p. 124), and in a previously written, but subsequently published, Paper (1889a, p. 65), he describes G. isolata, n. sp., from the Bahamas. We are able to extend the geographical distribution of the genus, and at the same time give ourselves the pleasure of associating one of our new species with the name of our esteemed colleague, Prof. J. Playfair McMurrich, of Haverford College, Pa., U. S. A., to whom we have so often referred in these pages.

Besides the type species, G. rusei, from St. Thomas, Duchassaing and Michelotti (1860) describe G. clavata, Duch. (St. Thomas and Guadeloupe), G. swiftii, D. & M. (St. Thomas), and G. brevis, Duch. (Antilles).

In 1866 they state that "perhaps G. swiftii may be better placed in the genus Bergia." From the figure (1860, pl. viii., pp. 17 and 18) it appears to closely resemble a Sarcodictyon, but in the later Memoir the authors state that it has 24 biserial tentacles. It is certain that this is not a synonym for Parazoanthus axinellae, as Andres suggests (1884, p. 311). Anyhow it is clear that these authors had no very definite conception of their own genus, for neither G. swiftii nor G. brevis would appear to belong to the same genus as the type species, nor is it certain that G. clavata does either.

It is difficult to understand why Andres (1884, p. 318) has regarded G. brevis as a synonym of two or three species of Epizoanthus. Gray (1867, p. 238) has added to the confusion by placing Z. sulcatus, Gosse, in this genus; but it is probable as McMurrich suggests, that Triga philippinensis, Gray (1867, p. 239), may belong to the genus in question. Gray's description of the genus Triga:—"The coral sub-cylindrical, solitary, attached, with a rather expanded base; outer coat coriaceous, sandy, concentrically wrinkled"; and of the type species:—"Coral sub-cylindrical, clavate, rather narrowed near the base, concentrically wrinkled; end convex, obscurely radiately striated; hab. Philippines, attached to small pebbles (Cuming). The coral varies from an inch to an inch and a-half in length"—agrees very well, except for size, with our new species; but without microscopical examination it would be impossible to determine with certainty even the genus of Gray's species.

The only known species of this genus are G. rusei, D. & M., G. isolata, McM., G. macmurrichi, n. sp., and G. mutuki, n. sp.

TORRES STRAITS SPECIES OF THE GENUS GEMMARIA.

G. macmurrichi, n. sp.
G. mutuki, n. sp.
Gemmaria macmurrichii, n. sp.

(Pl. lxii., fig. 11; Pl. lxiii., fig. 7.)

Form.—Erect, rigid, wider above than below; upper portion of contracted specimen with minute radiating corrugations.

Colour.—Sandy.

Dimensions.—Height, 13 mm.; diameter, 3·5 mm. above, 2 mm. below.

Locality.—Channel between Mer and Dauar, Murray Islands. 20 fathoms. Mar. 16, 1889. One specimen only.

Body-wall (Pl. lxiii., fig. 7).—The ectoderm is discontinuous, being broken up by thick, irregular strands of mesogloea, which unite to form a distinct peripheral layer lying beneath the cuticle. The ectodermal cells are for the most part disintegrated in our specimen, their contents adhering to the surrounding mesogloea and leaving an empty space in the centre. The incrustations consist chiefly of coarse grains of calcareous sand, but a few silicious sponge spicules are also present, and are left after decalcification. Beneath the incrustations lies an encircling sinus, which is, however, so much interrupted by the mesogloea as to appear in horizontal section as a circular series of lacunæ, each lacuna lying immediately below the union of a mesentery with the body-wall, two or three lacunæ being occasionally united by a fine canal. As the base of the polyps is approached the lacunæ gradually become smaller and finally disappear. It thus appears that the body-wall is pierced by a number of canals, which run vertically upwards from near the base to the disc of the polyp; these canals being occasionally connected with each other by much finer crossing canals. Similar fine canals are occasionally to be found running from the vertical canals outwards towards the ectoderm. Cell islets are scattered abundantly through the mesogloea, as also are single cells elongated into delicate fibrils connected both with endoderm and mesogloea, such as we have described in other species of Zoaanthæ. Large lacunæ, densely filled with deeply staining granules, are numerous at the base of the polyp. These are clearly connected with the mesenterial canals which arise in this region. They seem to be of ectodermal origin. The endoderm which lines the column is not very well preserved, but it appears to form a regular layer of medium thickness. The muscular layer is well developed in the upper part of the column. Lower down it is weaker.

Sphinctermuscle.—The sphinctermuscle is single, mesogloéal, and is well developed.

Disc and tentacles.—Unlike the two species of Gemmaria described by McMurrieh, the ectoderm of the disc and tentacles contains no zooxanthellæ, nor have we observed them in the endoderm either. The ectodermal muscular layer is fairly
well developed in our specimen, whilst in his it is very weak (1889, p. 124). Cell enclosures (similar to those described and figured by McMurrich) are found in the disc of *G. macmurrichi*. Foreign bodies are occasionally found embedded in the mesogloea of this region.

**Esophagus.**—The tissues of the oesophagus are badly preserved in our specimen. There is a slight thickening of the mesogloea at the groove, but we are unable to give further particulars.

**Mesenteries.**—The mesenteries are arranged as in other Brachycneminae. The mesogloea is well developed in both imperfect and perfect mesenteries. The muscular layer appears to be feebly developed, the mesogleal plaitings not being well marked. A vertical canal runs through each mesentery, from the base of the polyps to the disc; in many cases it appears to divide, giving rise to two or more canals in the oesophageal region. The reflected ectoderm and the filaments are so badly preserved that it is impossible to make out the particulars of their arrangement. The endoderm of the mesenteries is very similar to that which lines the body-wall.

**Gonads.**—There were no gonads in our specimen.

This species can easily be distinguished anatomically from the two species investigated by McMurrich, but externally they appear to be very similar.

**Gemmaria mutuki, n. sp.**

(Pl. lx1., fig. 10.)

**Form.**—Erect, wider above than below; 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.**—Grayish-white in spirit.

**Dimensions.**—Height, 10—12 mm.; average diameter, 4.5 mm.

**Locality.**—Mabuiag, 6th October, 1888; 5 specimens.

We have named this species after a local hero, Mutúk by name, whose adventures are recorded in the Journal of the Folk-lore Society, “Folk-lore,” I., 1890, p. 56.

**Body-wall** (fig. 1, p. 690).—The ectoderm is continuous, and is covered by a thin cuticle to which numerous diatoms adhere. Occasional zooxanthellae are to be found in the ectoderm. The mesogloea is rather thin relatively to the diameter of the polyp. Numerous incrustations are embedded in the mesogloea. They are chiefly spicular; ascidian as well as sponge spicules being frequently found. Grains of sand are
also present. Cell enclosures consisting for the most part of lacunae are very numerous in the mesogloea. There is no regular series of canals or of lacunae lying at the union of each mesentery with the body-wall, such as we have described for *G. macmurrichi*. In some parts of the wall, the lacunae lie so close together beneath the incrustations, as to suggest an interrupted encircling sinus; but for the most part they are irregularly scattered through the mesogloea. Zooxanthellae are found in many of these lacunae. The endoderm forms a uniform layer of moderate thickness in which zooxanthellae are very numerous. The muscular layer is well developed.

*Sphincter muscle.*—The usual single mesogloal sphincter muscle is present.

*Disc and tentacles.*—As in the body-wall, zooxanthellae are present in both ectoderm and endoderm in this species, though they are much less abundant in the former than in the latter layer. The ectodermal muscular layer is rather weak. In both these features it will be seen that *G. mutuki* differs from *G. macmurrichi*, and resembles McMurrich’s two West Indian species. The mesogloea of the disc in this species also contains cell enclosures.

*Esophagus.*—The groove is well marked, and of the truncated form described and figured by McMurrich for *G. isolata* (1889 a, p. 66, Pl. iv., fig. 20).

*Mesenteries.*—The mesenteries have the usual brachyclenic arrangement. The mesogloea is fairly well developed; the musculature is rather weak. Each mesentery contains a single basal canal, which does not divide in the oesophageal region as in *G. macmurrichi*, but runs up vertically from the base of the polyp almost to the disc. The tissues in the lower part of the coelenteron in our specimen are unfortunately not sufficiently well preserved for us to give details regarding the mesenterial filaments.

*Gonads.*—Numerous ripe sperm cells are present in the coelenteron of the specimen cut by us.

Externally this species may be distinguished from *G. macmurrichi* by its shorter, more stumpy form. Anatomically it differs from *G. macmurrichi* in the presence of numerous zooxanthellae, in the continuous ectoderm, and in various other points, which will be seen by comparing our description of the two species. Outwardly, *G. mutuki* may also be readily distinguished from the two West Indian species, but in several anatomical points, referred to above, it seems to agree more nearly with them than with *G. macmurrichi*.
Palythoa, Lamx., 1816.

Mammillifera (pars), Blainville, 1830. Polythoa (Corticithoa), Andres, 1884.

Brachyenchymic Zoanthæ with a single mesogloenal sphincter muscle. The body-wall is incrusted. The ectoderm is continuous(?); the mesogloea contains numerous lacunæ, and occasionally canals. Dioecious. Polyps immersed in a thick coenenchyme, which forms a massive expansion.

The genus Palythoa was founded by Lamouroux (1816, p. 359) for the reception of two species which had previously been described and figured by Ellis and Solander as Aleyonum mammillosum and A. ocellatum (1786, pp. 179, 180, Pl. 1, figs. 4—6). Palythoa is thus defined by Lamouroux:—"Polypier en plaque étendue, couverte de mamelons nombreux, cylindriques, de plus d’un centimètre de hauteur, réunis entre eux; les cavités ou cellules isolées, presque cloisonnées longitudinalement et ne contenant qu’un seul polype."

Palythoa mammillosa is evidently regarded by Lamouroux as the type species of the genus. He reproduces Solander’s figure of this species, but not that of P. ocellata, of which he merely gives a description. Unfortunately a Latinized version of the French name "Palythoé Etoillée," given by Lamouroux to P. mammillosa, has been added at the bottom of his plate—a circumstance which has given rise to some confusion.

In 1817 Lesueur, being evidently unacquainted with Lamouroux’s work, erected the genus Corticifera for two West Indian species which he named C. glareola and C. flava. These species are evidently very nearly allied to P. mammillsum and P. ocellata: indeed Lesueur queries whether C. flava is not synonymous with Aleyonum ocellatum, Ellis and Sol.; and his definition of the genus Corticifera agrees very nearly with that of Lamouroux for Palythoa.

Subsequent naturalists have, with very few exceptions, recognized the priority of Lamouroux’s genus, and have applied the name Palythoa to all those Zoanthæ which are incrusted with sand, and are immersed to a greater or less extent in the coenenchyme, forming corticiferous expansions. In this sense Verrill used the term in 1869, and Hertwig in 1882 adopted the same classification.

Unfortunately the genus Palythoa has also been occasionally extended to include Zoanthæ which are incrusted with sand, but which are united only at the bases, forms which are included in the genus Epizoanthus, as defined by Verrill (1869, p. 437). Amongst the species to which the name Palythoa was thus mistakenly applied was a form with ribbon-like coenenchyme and exsert polyps, described by Schmidt as P. axinellæ (1862, p. 61).
In 1885 Erdmann, investigating the anatomy of a number of forms which, to judge from their outward characters, should all be relegated to the genus Epizoanthus, discovered that, in reality, they belonged to two distinct natural genera, distinguished by the circumstance that some of them possessed a single mesogleal sphincter muscle, whilst in others the sphincter was endodermal. Amongst the latter was Schmidt’s species *P. axinellae*. Those species which possessed a mesogleal sphincter muscle Erdmann retained in the genus Epizoanthus. Those which had an endodermal sphincter, he placed in the genus Palythoa, ignoring *P. mammillosa*, and adopting *P. axinellae* as typical of the genus, thereby excluding the type species, as well as numerous closely allied forms which had hitherto borne the name *Palythoa*.

It was now necessary to find another name for these forms, and Erdmann consequently revived Lesueur’s genus Corticifera, a genus which, as we have pointed out above, was synonymous with Palythoa, but had to give place to that genus on the grounds of priority. To the former definition of the genus Corticifera Erdmann added certain anatomical characters—namely, the “micro-typal” (brachycnemic) arrangement of the mesenteries and the presence of a single mesoglea sphincter muscle. These anatomical characters have been shown to be present in all the species recently investigated which are included in Lamouroux’s Palythoa and in Lesueur’s Corticifera, including the type species *C. glareola* (re-examined by M‘Murrich, 1889, p. 122). It therefore appears that they all belong to one and the same morphological genus, which, as we have shown, must, according to the laws of priority, be known as Palythoa. To sum up, the argument may be briefly stated as follows:—Palythoa, Lamx. = Corticifera, Les. = Palythoa, Verrill, &c. Schmidt and others extended Palythoa to include *P. axinellae* and similar species, thus, unconsciously, making the genus Palythoa both macro- and brachycnemic.

Erdmann restricted the genus Palythoa to the non-typical macrocnemic extension, and revived Corticifera for the typical brachycnemic species. We restore Lamouroux’s genus, discard Corticifera, and erect a new genus, Parazoanthus, for *P. axinellae* and allied species.

As regards *P. mammillosa*, the type species of Palythoa, we may say that we are strongly inclined to regard *C. lutea* of Hertwig (1888, p. 44, Pl. 1., fig. 6) as being synonymous with *P. mammillosa*. M‘Murrich agrees with us in regarding Hertwig’s identification of his West Indian form with Quoy and Gaimard’s *Mammillifera lutea*, from the Fiji Islands, as doubtful in the extreme; but he is inclined to believe Hertwig’s species to be identical with *C. glareola*, which he describes (1889, p. 122). However this may be, we feel quite justified in assuming that the anatomical characters of *P. mammillosa* are similar to those of all the other species possessed of similar outward characters, which have been anatomically examined.
TORRES STRAITS SPECIES OF THE GENUS PALYTHOA.

P. howesii, n. sp.
P. kochii, n. sp.
P. coesia (?), Dana.

PALYTHOA HOWESII, n. sp.

(Pl. lx., fig. 13; Pl. lxiii., fig. 8.)

Form.—Polyps scarcely projecting above the surface of the coenenchyme when contracted, and then, in most cases, only the one side is prominent; in other words, the side is almost invariably entirely sunk. Coenenchyme, thick, incrusting. The polyps are arranged in indefinite, roughly parallel rows. Owing to the partial immersion of the polyps the prominent portions of contiguous polyps have a tendency to form zigzag lines. The whole surface is very rigid and rough, owing to the incrustation of sandy particles.

Colour.—Sandy.

Dimensions.—Average diameter of polyps, 7 mm.

Locality.—Fringing reef, Thursday Island. One colony.

Named after Prof. G. B. Howes, of the Royal College of Science, London. [I would like to take this opportunity of acknowledging the assistance which my friend Professor Howes has rendered me from first to last in the storing and distribution of my Torres Straits collections.—A. C. H.]

Body-wall (Pl. lxiii., fig. 8).—As in other species of Palythoa, the body-wall and coenenchyme are indistinguishable. The ectoderm which covers the surface of the colony is much torn, fragments of it alone adhering to the mesogloea; these pieces are further broken by irregular projections of the mesogloea, which somewhat resemble the mesogloeal strands found in various other species of Zoanthæ, but they do not appear to unite in this case to form a peripheral layer of mesogloea. In most cases no cuticle is to be seen, but in one or two places we have found a thin cuticle, and it seems probable that in a normal condition such a cuticle covers the surface of the ectoderm. The mesogloea is very thick, and the incrustations are chiefly found in the outer portion. The incrustations consist of coarse grains of sand, and are very numerous. Lacunæ, some of which are clearly connected with the ectoderm, are scattered through the mesogloea. In some cases
the canals in the mesenteries, which are extremely well marked, are distinctly connected with the spaces in the body-wall. Large yellowish nematocysts are present in the outer ectoderm, in many of the lacunæ of the mesogloea, and in the mesenteric canals, being especially numerous in the latter. A very few zooxanthellæ are also present. Besides the lacunæ, numerous isolated cells are enclosed in the mesogloea, many of them being drawn out into the fine protoplasmic threads found in other species of Zoanthæ. The endoderm is granular, of uniform thickness, and contains occasional zooxanthellæ. The usual diffuse muscular layer is present.

_Sphinctor muscle._—The single mesogloal sphincter muscle is well developed.

_Disc and tentacles._—The ectoderm is thick, and in the tentacles the ectodermal muscular layer is well developed, the mesogloal folds being complicated and branching. The mesogloea also forms a thick layer and often contains cell enclosures. The endoderm is very thin.

_Esophagus._—The ectoderm of the æsophagus was not well preserved in our specimens, so that it was not possible to determine its nature or arrangement in a normal condition. There is a well marked groove, and the mesogloea, which elsewhere is thin, becomes much thickened in this region.

_Mesenteries._—The mesenteries present the usual microcnemic arrangement. The imperfect mesenteries are usually well developed. The ectoderm of the æsophagus appears to be reflected in the usual manner, but owing to its bad preservation it is not possible to determine the exact nature of its arrangement. The mesogloea is well developed, and in each mesentery it contains one or more sinuses or canals which extend throughout the entire height of the mesentery. These sinuses contain numbers of large nematocysts, similar to those found in the ectoderm of the body-wall. The muscles of the mesenteries are not strongly developed. They form almost simple layers.

_Gonads._—The sexes are distinct; we found female, but no male gonads, in several of the polyps which we examined. They were all taken from the same colony.

**Palythoa kochii**, n. sp.

(Pl. lxii., fig. 12; Pl. lxiii., fig. 9.)

_Form._—Polyps projecting slightly above the surface of the coenenchyme; coenenchyme incrusting, of moderate thickness. Polyps so crowded as to usually have a polygonal contour. The whole surface is incrusted with calcareous particles, etc. Twenty capitular ridges and furrows. Tentacles, 40. Mouth large.

_Colour._—Colour of colony, finely speckled buff and cream, each polyp demarcated by a pale border; tentacles similar, but translucent. Disc thin, translucent,
the dark interval cavity shining through; very finely dotted with brown and opaque white. Esophagus gray, furrowed. Capitular ridges whiter than the rest of the polyp.

**Dimensions.**—Diameter of polyps about 5 mm.

**Locality.**—Fringing reefs, Thursday Island, and Mabuiag.

This species is named in honour of our distinguished German colleague, who was the first to discover the precise arrangement of the mesenteries in the Zoanthæ.

**Body-wall** (Pl. lxiii., fig. 9).—As in the last species the body-wall and coenenchyme may be regarded as one. The ectoderm, where present, is continuous, and is covered by a thin cuticle. Incrustations, consisting of spicules and grains of sand (the latter being for the most part less coarse than those found in *P. howesii*), form a dense border at the union of the ectoderm with the mesogloea. They are scattered more sparingly through the deeper parts of the mesogloea. Lacunæ, canals, and cell islets are found throughout the mesogloea. Nematocysts are present in both the ectoderm and the lacunæ. Zooxanthellæ are also found in the ectoderm and lacunæ, as well as in the endoderm. The endodermal muscle is well developed. The endoderm forms a uniformly thin layer.

**Sphincter muscle.**—The mesogloal sphincter is long and well developed.

**Disc and tentacles.**—The structure of the disc and tentacles is very similar to that found in *P. howesii*.

**Esophagus**—The ectoderm of the cesophagus is not well preserved, but it appears to be thrown into well marked folds. There is a very slight groove, and no appreciable thickening of the mesogloea in this region.

**Mesenteries.**—The mesenteries are arranged as in other Brachycneminæ. The imperfect mesenteries are well developed. The reflected ectoderm is not well preserved, but is evidently arranged in the ordinary manner. Sinuses, similar to those found in *P. howesii*, are found in the mesenteries of this species also. The muscular layers are very simple, there being apparently no mesogloal plaitings.

**Gonads.**—We found male gonads in several of our specimens, but no female organs were present.

**Palythoa caesia (?), Dana.**

(Pl. lxi., fig. 14.)

*Palythoa caesia* :


**Form.**—Polyps slightly projecting above the surface of the coenenchyme when contracted. Coenenchyme incrusting in small, ovoid, concavo-convex masses of
moderate thickness. Polyps large, not crowded, of rounded contour. The whole surface is incrusted with calcareous particles. About twenty capitular ridges.

**Colour.**—Grayish-white in spirit specimens.

**Dimensions.**—Diameter of polyps about 9 mm. The colonies in the specimens before us average about 50 cm. by 40 cm.

**Locality.**—Reefs, Torres Straits.

We have doubtfully referred this species to *P. caesia*, which was collected by the United States Exploring Expedition at Fiji. The size and disposition of the polyps are fairly similar in the two forms; but the coenenchyme of ours is less convex. From the specimen figured (Pl. lxi., fig. 14), it would seem that the colony divides after it has attained a certain size.

**Body-wall.**—In its anatomy this species is in most respects very similar to that of *P. kochii*. The ectoderm is covered by a thin cuticle, and is continuous. It contains nematocysts and zooxanthellae. Incrustations are even more numerous than in *P. kochii*, and they penetrate the mesogloea, which separates the polyps to a greater extent than in that species. They consist of sponge and ascidian spicules, foraminifera, &c., as well of great numbers of grains of sand. Lacunae of variable size are very numerous in the mesogloea. In some cases a great number of these lacunae placed close together form a sort of spongy or vesicular sheath round an individual polyp. Nematocysts are commonly to be met with in the lacunae. The endoderm is not very well preserved, but it appears to form ridges between the mesenteries, rather than a thin uniform layer as in *P. kochii*. The endodermal muscular layer appears to be well developed:

**Sphincter muscle.**—The single mesogleal sphincter is a strong one.

**Disc and tentacles.**—The disc and tentacles are very similar in structure to those in the last two species, the ectoderm being remarkably thick.

**Esophagus.**—Nematocysts are very numerous in the ectoderm of the esophagus. There is a well marked groove.

**Mesenteries.**—The arrangement of the mesenteries is brachycnemic. The
mesenteries in other respects seem to be very similar to those of \textit{P. howesii} and \textit{P. kochii}. Well marked sinuses extend through each mesentery from the base to the disc.

\textit{Gonads}.—We have found no generative organs in this species.

The more irregular disposition of the polyps distinguishes \textit{P. kochii} from \textit{P. howesii}, in which they are arranged more or less in rows. The zigzag appearance due to the partial immersion of the polyps is very characteristic of \textit{P. howesii}. It would require considerable care to distinguish between \textit{P. kochii} and certain other species of the genus. \textit{P. cœsia}, as identified by ourselves, is easily distinguishable from the preceding species on account of the large and non-crowded polyps and the apparently smaller size of the colonies; but we would like to add another warning as to the extreme difficulty in identifying the species of this genus.

\textbf{Sphenopus}, Steenstrup, 1856.

Free, solitary, brachynemic Zoanthææ, with a single, very long, mesogloæal sphincter muscle. The body-wall is incrusted. Cell islets present in the mesogloæa.

\textit{Sphenopus arenaceus}, Hertwig.

\textit{Sphenopus arenaceus}:


Hertwig says, in his first report of this species:—"Habitat—Cape York? (the title of the label enclosed with the preparation was nearly entirely destroyed by the rough surface of the animal, and could not be exactly made out), one specimen." In the Supplement he says:—"Habitat—Station 187, Torres Strait, Australia, September 9, 1874; 6 fathoms. Two specimens. . . . In the 'Challenger' material I have found four further examples of the genus Sphenopus; two of these I have determined as \textit{Sphenopus arenaceus}, on account of their rusty red tint, and other two \textit{Sphenopus marsupialis}, in consequence of the earthy-gray colour and the absence of a stalk." The last being a character of his other new species, \textit{S. pedunculatus} (\textit{i. c.} p. 49), from off Panay, Philippine Islands.

This is the only Zoanthææ previously recorded from Torres Straits, and it does not occur in our collection. Thanks to the kindness of Professor F. Jeffrey Bell, of the British Museum, we have been able to examine some specimens of \textit{S. marsupialis} which were given to him by Edgar Thurston, Esq., of the Central Museum, Madras, who collected them at Madras.

Hertwig gives no characters by which this species can be distinguished from.
698  Reports on the Zoological Collections made in Torres Straits, 1888–1889.

*S. marsupialis*, and we agree with him when he says it is "desirable that with an opportunity of more abundant and fresh material, a renewed study should be undertaken to decide whether the received specific characters are variable, and whether all three species should not be united in the single *Sphenopus marsupialis* (l. c. p. 52).

Sub-family.  **Macrocnenmæ.**

**PARAZOANTHUS**, Hadd. & Shackl., 1891.

Macrocnenmic 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 mesogloea. Dioecious. Polyps connected by thin coëneenchyme.

This genus is established by us in our second part of the Revision of the British Actinææ (1891, p. 653), to which the reader is referred for fuller details.

TORRES STRAITS SPECIES OF THE GENUS PARAZOANTHUS.

*P. dichroicus*, n. sp.

*P. douglasi*, n. sp.

**Parazoanthus dichroicus**, n. sp.

(Pl. lx., fig. 15; Pl. lxii., fig. 5.)

_Fom._—Body short, encrusted with sand and spicules. Capitulum with about eighteen distinct ridges. Coëneenchyme encrusting a specimen of *Plumularia ramsayi*.

_Colour._—Body and coëneenchyme, gray; capitulum, pale-yellow.

_Dimensions._—2–2·5 mm. in height; 1·25–1·5 mm. in diameter.

_Locality_—Channel between Mer and Dauar, about 20 fathoms, Jan. 6, 1889. One colony.

This species rendered the alcohol in which it was preserved strongly dichroic—the colours being yellow and violet; we have emphasised this fact in its name, which is also appropriate on account of the gray and yellow colour of the polyps.

_Body-wall._—The body-wall is thickly incrusted with foreign bodies, particles of sand, diatoms, ascidian and sponge spicules, &c. (Pl. lxii., fig. 5). These are embedded in the mesogloea, the ectoderm having for the most part disappeared from
the surface of our specimens. Where present the ectoderm appears to be continuous. It is not penetrated by strands of mesogloea, nor is there a peripheral layer of mesogloea. The cuticle is very delicate, and difficult to discern. Beneath the incrustations, and separated from the endoderm by a narrow band of mesogloea, is an encircling sinus filled with dark brown granular pigment. It is crossed at intervals by strands of mesogloea. A few branching canals connected with the sinus run outwards through the mesogloea among the incrustations. Small, round or oval groups of cells, the cell-islets of Erdmann, are scattered throughout the mesogloea; a very few pigment granules can be seen in some of them. We have not observed any connexion between the sinus or the canals connected with it and these islets. The endoderm is richly pigmented. We have seen no zooxanthellae.

The capitulum, which in contracted specimens is thrown into deep folds, is also incrusted; but there is a much larger proportion of spicules and relatively fewer sand particles than in the column. The encircling sinus is not continued into the capitulum.

_Sphincter muscle._—The endodermal sphincter is supported on slightly branched plaitings of mesogloea. Near the upper extremity (in contracted specimens) it appears to become embedded in the mesogloea, a few simple cavities being visible in our sections.

_Tentacles._—The ectoderm of the tentacles is thick. The nuclei are scattered diffusely through the outer part, leaving a clear band next the muscular layer. Small nematocysts of the usual description are present. The mesogloea is thin and almost homogeneous, a very few cell-islets being present. The endoderm contains a few zooxanthellae, and occasional pigment granules.

_Disc._—The ectoderm of the disc is very similar to that of the tentacles, but it contains some pigment. Numerous cell-islets occur in the mesogloea.

_Öesophagus._—The ectoderm of the öesophagus stains more deeply than that of the disc or tentacles. It forms a simple layer, not being thrown into folds. The mesogloea is fairly thick, especially in the region of the groove, which is well marked.

_Mesenteries._—The mesenteries are arranged as in other Macrocenemine. The imperfect mesenteries are very slightly developed, projecting but little beyond the endoderm. The mesogloea of the mesenteries is thick, and contains cell-islets, but no canals or sinuses. The longitudinal muscles are well developed and supported on mesogloea folds. The endoderm resembles that which lines the body-wall.

_Gonads._—In one of the specimens cut by us male gonads were found.

_Parasites._—Small, oval, deeply pigmented bodies occur in many parts of the body in this species. They are evidently parasites, but we are unable to say anything further about them.
Parazoanthus douglasi, n. sp.

(Pl. lx., 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; coenenchyme incrusting.

Colour.—Sand colour.

Dimensions.—Height variable; largest specimens 8—9 mm.; diameter, 2—2.5 mm. The shorter specimens growing on flat surfaces are from 3—5 mm. in height, and 2 mm. in diameter.


[I have named this species in honour of the Hon. John Douglas, K.C.M.G., Government Resident at Thursday Island, Torres Straits, who assisted me as far as was in his power during my stay in Torres Straits.—A. C. H.]

Body-wall.—As in P. dichroicus, but little ectoderm remains on the body-wall of our specimens of P. douglasi, and that which does remain is continuous and covered by a very delicate cuticle. The incrustations, which penetrate the greater part of the thickness of the mesogloea, consist chiefly of sponge spicules (some of them being triradiate) with a few grains of sand, foraminifera, &c., amongst them. There is an encircling sinus which contains a few dark granules similar to those which are so abundant in P. dichroicus, but it is for the most part almost empty. It is crossed at intervals by the strands of mesogloea, and is connected with a system of branching canals, which run outwards through the incrustation. Cell-islets, though present, are not at all so numerous as in P. dichroicus. The endoderm forms a thin layer of uniform thickness. The muscular layer is feebly developed.

Capitulum.—The incrustations in this region are almost entirely confined to sponge spicules. The ridges, although not externally conspicuous, can be well seen in our transverse sections.

Sphincter muscle.—The sphincter muscle is entirely endodermal. The mesogloeaal plaitings are regular and simple.

Disc and tentacles.—The structure of disc and tentacles is very similar to that of P. dichroicus, but there appear to be no enclosures of any kind in the mesogloea.

Ösophagus.—The ectoderm of the ösophagus is thrown into slight folds. There is a distinct groove, the mesogloea being much thickened in this region.

Mesenteries.—The arrangement of the mesenteries is brachycnemic. The imperfect mesenteries are even more feebly developed than in P. dichroicus, being in many cases hardly discernible. The mesogloea forms a fairly thick layer,
without enclosures of any kind. It is thrown into very slight plaitings to support the longitudinal muscles, which are not well developed. The parieto-basal muscles are also feebly developed. The endoderm of the mesenteries forms a thin layer similar to that which lines the body-wall.

Gonads.—No gonads were found in our specimens.

Parasites.—We found that many of our specimens of this species were infested by a copepod which deposits its egg in the cælenteron or cælenteric canals of the polyp. The capsules are paired, and contain a large number of ova. We have found them in the nauplius stage, as well as in other stages of development. We have two specimens of the copepod, but are unable to say whether these are adult or not. The capsules form distinct swellings of the body-wall of the actinian. This fact leads us to suppose that the copepod remains within the cælenteric cavities while the capsule is developing, and when the latter is ripe it breaks away from it (Pl. lxi., figs. 19—22).

Small oval parasites, similar to those found in P. dichroicus, are also found in P. macmurrichii.

The larger size and uniform colouration of P. douglasii enable it to be easily distinguished from P. dichroicus.
EXPLANATION OF PLATE LXI.
PLATE LXI.

Fig.
1. Zoanthus coppingeri, n. sp. (p. 676). Natural size; spirit specimens.
2. Zoanthus coppingeri. Drawn from living specimen by A. C. H.
3-4. Zoanthus jukesii, n. sp. (p. 678). Sketched from life by A. C. H.
5. Zoanthus jukesii. Natural size; spirit specimens.
6. Zoanthus maclellivrayi, n. sp. (p. 680). Twice natural size; drawn from spirit specimens by A. C. H.
7. Isaurus asymmetricus, n. sp. (p. 684). Natural size; drawn from life by A. C. H.; one specimen is drawn, showing the smooth side.
9. Isaurus asymmetricus. Small variety from Murray Island; natural size; drawn from life by A. C. H.
10. Gemmaria mutuki, n. sp. (p. 689). Natural size; spirit specimens.
11. Gemmaria macmurrichi, n. sp. (p. 688). Twice natural size; drawn from spirit specimen by A. C. H.
13. Palythoa howesi, n. sp. (p. 693). Portion of colony; natural size; spirit specimen.
15. Parazoanthus dichroicus, n. sp. (p. 698). Natural size; spirit specimen.
16-17. Parazoanthus douglasi, n. sp. (p. 700). Natural size; spirit specimens.
18. Parazoanthus douglasi. Natural size; portion of a dried colony incrusting stones; dried specimen.
19-22. Copepod Galls on P. douglasi—
   19. Portion of coenenchyme-wall of gall.
   20. Side view of one of the egg-capsules in situ.
   22. Two empty galls in base of polyp.

[All the above are in the British Museum, with the exception of fig. 11, of which the single specimen obtained was utilised for anatomical examination.]
EXPLANATION OF PLATE LXII.
PLATE LXII.

LETTERING ADOPTED IN THE FIGURES.

- c.i., . . . . cell-islets.
- cut., . . . . cuticle.
- ect., . . . . ectoderm.
- ect. can., . . . ectodermal canal.
- enc. sin., . . . encircling sinus.
- end., . . . . endoderm.
- incr., . . . . incrustation.
- mes., . . . . mesogloea.
- mes. lac., . . . mesenterial lacuna.
- mes. sin., . . . mesenterial sinus.
- m. f., . . . . mesenterial filament.
- nem., . . . . nematocyst.
- ov., . . . . ovum.
- par., . . . . parasite.
- x., . . . . axial support of incrusting forms.
- z., . . . . zooxanthella.

[The axial support in fig. 5 is a Hydroid.]

Fig.
1. *Zoanthus coppingeri*, n. sp. (p. 676). Transverse section through the base of the body-wall, \( \frac{2}{A} \).
2. *Zoanthus jukesii*, n. sp. (p. 678). Transverse section through the base of the body-wall, \( \frac{2}{A} \).
3. *Zoanthus macgillivrayi*, n. sp. (p. 680). Transverse section through the base of the body-wall, \( \frac{2}{A} \).
4. *Isaurus asymmetricus*, n. sp. (p. 684). Transverse section through the base of the body-wall, \( \frac{4}{a^{8}} \cdot \frac{10}{1} \).
5. *Parazoanthus dichroicus*, n. sp. (p. 698). Transverse section through the base of the body-wall, \( \frac{2}{B} \).
6. *Parazoanthus douglasi*, n. sp. (p. 700). Transverse section through the base of the body-wall, \( \frac{2}{B} \).

* These letters of magnification refer in all cases to Zeiss' system.
PLATE LXIII.

LETTERING ADOPTED IN THE FIGURES.

br. cn. mes., . . . brachycnemic mesentery (the sulco-

m., . . . . mesoglea.
sulcar lateral mesentery).

mes. can., . . . mesenterial canal.

cal., . . . . celenteron.
m. sph. m., . . . mesogloval sphincter muscle.

co., . . . . cuticle.

ncm., . . . . nematozyst.

decan., . . . lacuna due to the decalcification of

a., . . . . . asosophagus.
an incrustation.

s. d., . . . . sulcar directive mesenteries.

et., . . . . . ectoderm.

s. gr., . . . . sulcar groove.

et. b., . . . . ectodermal bay.

sl. d., . . . . sulcular directive mesenteries.

een., . . . . endoderm.

vert. can., . . . vertical canal.

end. can., . . . endodermal canal.

eooz., . . . . zooxanthella.

Fig.

1. Zoaanthus jukesii, n. sp. (p. 678). Transverse section through the oesophageal region of the

column, \( \frac{4}{a^* 10} \).

2. Zoaanthus macgillivrayi, n. sp. (p. 680). Transverse section through the lower portion of the

column, \( \frac{3}{a^* 8} \).

3. Isaurus tuberculatus (Gray), (p. 617 of British Zoaanths). Section through an ectodermal bay, \( \frac{2}{B} \).

4. Isaurus asimetricus, n. sp. (p. 684). Vertical section through a sphincter muscle, \( \frac{2}{a^* 10} \).

5. Isaurus asimetricus. Transverse section through a portion of the centre of the base of the

column, \( \frac{2}{D} \).

6. Isaurus asimetricus. Transverse section through the periphery of the body-wall, \( \frac{2}{D} \).

7. Gemmarea macmurrichi, n. sp. (p. 688). Transverse section through the body-wall (decalcified), \( \frac{2}{B} \).

8. Palythoa kowesii, n. sp. (p. 693). Transverse section through the body-wall (decalcified), \( \frac{2}{B} \).

9. Palythoa kochii, n. sp. (p. 694). Transverse section through the body-wall, \( \frac{2}{B} \).
EXPLANATION OF PLATE LXIV.
### PLATE LXIV.

**LETTERING ADOPTED IN THE FIGURES.**

<table>
<thead>
<tr>
<th>Term</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>cuticle</td>
<td>cu.</td>
<td>mesenterial canal</td>
</tr>
<tr>
<td>m. sph.</td>
<td>mes. sph.</td>
<td>mesenterial sinus</td>
</tr>
<tr>
<td>ectoderm.</td>
<td>ect.</td>
<td>mesenterial filament</td>
</tr>
<tr>
<td>can.</td>
<td>mes. can.</td>
<td>nerve-cell</td>
</tr>
<tr>
<td>sphincter</td>
<td>mes. sphincter</td>
<td>nematocyst</td>
</tr>
<tr>
<td>end. b.</td>
<td>endodermal bay</td>
<td>oesophagus</td>
</tr>
<tr>
<td>canalicul.</td>
<td>mes. canaliculus</td>
<td>ovum</td>
</tr>
<tr>
<td>mus.</td>
<td>endodermal</td>
<td>parieto-basilar muscle</td>
</tr>
<tr>
<td>bay</td>
<td>endocan.</td>
<td>reflected ectoderm</td>
</tr>
<tr>
<td>canal</td>
<td>mes. canal.</td>
<td>sperm-cell (testis)</td>
</tr>
<tr>
<td>tentacle</td>
<td>endocan.</td>
<td>tentacle</td>
</tr>
<tr>
<td>food-ball</td>
<td>f. b.</td>
<td>zooxanthella</td>
</tr>
<tr>
<td>long.</td>
<td>l. m.</td>
<td></td>
</tr>
<tr>
<td>mesogloea</td>
<td>mes.</td>
<td></td>
</tr>
</tbody>
</table>

---

**Fig.**

1. *Zoanthus coppingeri*, n. sp. (p. 676). Transverse section through the body-wall, $\frac{2}{D}$.

2. *Zoanthus coppingeri*. Transverse section through the wall of a tentacle, $\frac{2}{D}$.

3. *Zoanthus coppingeri*. Vertical section through the half of a polyp; slightly diagrammatic; the ectoderm, endodermal canals, mesogloea, mesenteric canals, gonads, and sphincter muscle are coloured red; the endoderm and the endodermal canals are coloured blue, $\frac{3}{\sigma}$.

4. *Zoanthus coppingeri*. Transverse section through a perfect mesentery, $\frac{2}{D}$.

5. *Zoanthus macgillivrayi*, n. sp. (p. 680). Vertical section through a portion of a polyp, $\frac{3}{\sigma}$.

6. *Zoanthus macgillivrayi*. Transverse section through part of a perfect mesentery, with reflected ectoderm, $\frac{2}{C}$.

7. *Zoanthus macgillivrayi*. Transverse section through a perfect mesentery, showing the upper portion of the mesenterial filament, $\frac{2}{C}$.

8. *Zoanthus macgillivrayi*. Transverse section through a perfect mesentery, showing the lower portion of the mesenterial filament, $\frac{2}{C}$.

9. *Isaurus asymmetricus*, n. sp. (p. 684). Transverse section through two perfect and one imperfect mesenteries in the oesophageal region; also showing an endodermal bay, $\frac{2}{A}$.
TRANSACTIONS (NEW SERIES).

Vol. I.—Parts 1-25.—November, 1877, to September, 1883.
Vol. II.—Parts 1-2.—August, 1879, to April, 1882.
Vol. III.—Parts 1-14.—September, 1883, to November, 1887.

VOLUME IV.

Part


3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.


5. A Revision of the British Actiniæ. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.


7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleosteans. By Ernest W. L. Holt, St. Andrew's Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.


12. A Revision of the British Actiniæ. Part II.: The Zoanthæ. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and Miss Alice M. Shackleton, B.A. Plates LVIII., LIX., LX. (November, 1891.) 3s. 6d.

13. Reports on the Zoological Collections made in Torres Straits by Professor A. C. Haddon, 1888-1889. Actiniae: I. Zoanthæ. By Professor Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and Miss Alice M. Shackleton, B.A. Plates LXI., LXII., LXIII., LXIV. (December 1891.) 3s.
XIV.


DUBLIN:
PUBLISHED BY THE ROYAL DUBLIN SOCIETY.
LONDON: WILLIAMS AND NORRIGATE.
PRINTED AT THE UNIVERSITY PRESS, BY PONSONBY AND WELDRICK,
PRINTERS TO THE SOCIETY.
1892.

Price Four Shillings.
XIV.


[Read January 20, 1892.]

[Communicated by the Honorary Secretaries.]

I.—INTRODUCTION.

It is proposed in this work to describe, and where desirable to figure, the fossil fishes whose remains have been discovered in the several coal fields of Great Britain. For the purposes of this work the Coal Measures will include all the strata between the uppermost bed of Millstone Grit at their base, and the Permian Rocks which immediately overlie them. The subject is a large one, and for convenience of publication, as well as in the preparation and arrangement of the material, it appears advisable to divide it into a series of monographs, commencing with the Elasmobranchii, and of this sub-class the Pleuracanthidæ will first receive attention. Except incidentally, the stratigraphical distribution of the fish-remains will be considered later, when all the available material shall have been examined and recorded.

I cannot neglect the present opportunity to express my indebtedness to those gentlemen having the charge of public or private museums, for their uniform courtesy and kindness in permitting me to visit their collections, and still more for the readiness with which such parts of the collections as were necessary for comparison or identification have been placed at my disposal. Amongst such instances I may mention the Natural History Department of the British Museum, Cromwell-road, London; the Museum of the Natural History Society of Northumberland, Durham, and Newcastle-on-Tyne; the Manchester Museum at the Owens College; the Woodwardian Museum at Cambridge; the Museums of the Philosophical Societies at Leeds, Halifax, and York; the Hunterian Museum at Glasgow, and the Museums of Science and Art at Edinburgh and Dublin.
Amongst the owners of private collections I am greatly indebted to my friends and co-workers, James Thomson, Esq., of Glasgow; Dr. J. R. S. Hunter, of Carluke, and R. Dunlop, Esq., of Airdrie, in Scotland; George Wild, Esq., of Bardsley, and James Nield, Esq., of Oldham, in Lancashire; Professor Louis C. Miall, of the Yorkshire College, and T. W. Embleton, Esq., of Methley, in Yorkshire; to William Dinning, Esq., of Newcastle, an able palæontologist, to whose manipulative skill science is indebted for some of the most beautiful examples figured in the present monograph, I owe many thanks. No worker in this branch of palæichthyology can afford to do without the assistance of John Ward, Esq., of Longton, in Staffordshire; his great collection, unique in many respects, and the result of many years of patient investigation, is invaluable; and to this collection, and the practical knowledge possessed by Mr. Ward, willingly placed at my disposal, I am under deep obligations. And lastly, to A. Smith Woodward, Esq., whose fellowship is very dear to me, I am indebted for many helpful courtesies and kindnesses, which may perhaps be more easily understood than expressed.

II.—CLASSIFICATION AND DESCRIPTION.

Class.—PISCES.

Sub-Class I.—ELASMOBRANCHII.

Order I.—Ichthyotomi (E. D. Cope and A. Smith Woodward).

*Syn.—Xenacanthidae, H. B. Geinitz, C. F. Lütken, Anton Fritsch; Pterygacanthidae, Ch. Brongniart.*

Endoskeletal cartilage permeated throughout with granular calcifications; notochord rarely or never constricted; calcifications of the sheath arrested at the most primitive rhachitomous stage, except in the caudal region. Neural and haemal arches and spines long and slender; with or without intercalary cartilages. Pectoral fins with long segmented axis (archipterygium).

Family.—PLEURACANTHIDÆ. A. Smith Woodward, Ch. Brongniart.

*Syn.—Xenacanthidae, Anton Fritsch.*

Body slender, but slightly depressed; mouth terminal; tail diphyceral; dorsal fin elongate, low, continuous along the back from a point shortly behind the head; slender interneural cartilages more numerous than the neural spines. Pectoral fin with biserial arrangement of cartilaginous rays.


Body comparatively elongated; skin destitute of shagreen; head large and depressed; cranium consisting of segments, more or less ossified, separated by sutures; mouth terminal, widely extended; jaws bearing numerous teeth (*Diplodus*), arranged as in the Selachii; notochord persistent; neural and hemal arches ossified, the ossification presenting a mosaic appearance due to granular calcifications; seven gill arches (Fritsch) the seventh arch without gills; gill rakers present (*Stemmatodus*); head surmounted by a spine, straight or slightly curved; opening of internal cavity of spine terminal; along some part of the surface extends two rows of denticles; these may be widely separated and lateral (*Pleuracanthus*); they may be in close proximity along the posterior surface (*Orthacanthus*) or the two rows may occupy any intermediate position between the two. Attached to the spine is a small cephalic fin; dorsal fin commencing immediately behind the head extends to the base of the caudal; the fine rays supported by interspinous and surapophysial bones more numerous than the neural spines; tail diphycecal with a pointed extremity; pectoral fins supported by a long articulated axis (archipterygium) with a bi-serial arrangement of semi-osseous...
lateral cartilages; ventral fins with an articulated axis supported by a pair of triangular pelvic cartilages and lateral cartilages on external surface; in the males the fins are provided with claspers; two anal fins placed one behind the other, attached to the haemaphyses by a series of intermediate ossicles.

The genus Pleuracanthus was instituted by Agassiz* and embraced a fish spine from the coal shales of Dudley; its surface was rounded and at the same time depressed and armed on each side by a range of denticles arched towards the base. The spine was considered to belong to an undescribed genus of the family of the Rays. One species was described, P. lavissimus, Ag.† A second species was referred to six years later, but not described, viz. P. planus, Ag., in the same volume, p. 177. This was from the Coal Measures in the neighbourhood of Leeds. The type specimen is in the Egerton collection at the Natural History Museum, London, and is now determined as the spine of a young example of P. lavissimus. Prof. Agassiz refers on the same page‡ to another spine, Orthacanthus cylindricus, Ag., from the Coal Measures at Leeds; and again when considering the defences of the Rays, O. cylindricus is described as a straight spine of cylindrical form armed with two rows of sharp denticles on the posterior surface. The spine is stated to be from the Coal Measures in the neighbourhood of Manchester. The near relationship of Orthacanthus with the genus Pleuracanthus is recognized.

In 1841, Mr. E. W. Binney first noticed certain teeth from the Lancashire coal field to which he appended the name Diplodus gibbosus.§ The specimen was figured but without description; the latter was given by Agassiz,|| and specimens were described from the Coal Measures of Staffordshire and of Carluke in Scotland.

Dr. Goldfuss¶ described a specimen ascribed to the genus Orthacanthus from the lower Permian Sandstones of Ruppersdorf in Bohemia exhibiting the upper surface of the head and a large portion of the body. The mouth was large and terminal with numerous rows of small three-pronged teeth. The spine, still in position, was embedded in a cartilaginous mass immediately behind the head. It was round, with a median ridge on the dorsal aspect; and on each side the ridge, separated by a narrow groove, was a row of denticles. The spine was on front of the first dorsal fin, considered subsequently by C. Brongniart,** as a cephalic fin. The second long dorsal fin was without spine. The pectoral arch is described as being built up, on either side of an internal bone, composed

¶ Beiträge zur vorweltlichen Fauna des Steinkohlengebirges, p. 23, pl. v., figs. 9–11, 1847, Bonn.
of a single piece, which towards its hinder part is bent on its outer edge in the form of a knee. This edge supports a number of fin-rays, the anterior ones fine and short, those behind longer and thicker. From the knee-shaped angle springs a strong distinctly jointed ray (axis of archipterygium). To this are attached, on its outer margin, seventeen thick strong rays; and on its inner margin a number of smaller and closer rays. In the Kuppersdorf specimen it is not clear by what means the knee-shaped bone was attached at its proximal extremity. The ventral fins are similarly connected to those of the pectoral. A broad, short geniculate bone was suspended from the vertebral column, and to this was attached an articulated primary ray as in the pectoral fin; but they differ from the pectorals in having lateral rays only on the outer margin.

M. Beyrich described and discussed, a year later, the relationship of a fish* similar in all essential respects to the Orthacanthus described by Goldfuss, except that in this specimen the spine was flattened before and behind, and had on each side rows of sharp, short, hook-shaped, backward-pointing teeth. To this fish the new generic name Xenacanthus was given, and the opinion expressed that Orthacanthus Dechenii of Goldfuss must be given up in its favour; and further that though the spine is evidently the same genus as the Pleuracanthus of Agassiz, which has priority, the latter is only known as the name of a spine, and consequently must give way to Xenacanthus, which represents a more or less perfect fish.

Sir Philip de Malpas Grey Egerton, at the meeting of the British Association at Glasgow, in the year 1855, drew attention to the generic identity of the spines called Pleuracanthus and Xenacanthus, and the teeth named Diplodus; and in 1857† he published a paper in the “Annals and Magazine of Natural History,” in which the claim of Pleuracanthus to priority over the other names is enforced, and consequently it should stand as the name of the genus.

It was suggested by Prof. H. B. Geinitz that the ventral plates might have been a sucker, and the fish allied to the genus Cyclopterus.‡

In 1867, Prof. D. Rudolph Kner published a memoir, “Ueber Orthacanthus Dechenii. Goldf. oder Xenacanthus Dechenii Beyr.”§ Specimens located in the museums of Dresden, Berlin, Breslau, Vienna, and others are described in detail. Kner argues that the two genera named, along with Diplodus teeth, are identical, as was stated by Goldfuss twenty years previously. The fish is described as having a large head, somewhat flat, with a large rounded terminal mouth. The pectoral fins were broadly expanded and the body tapered towards the tail. The

---

* Bericht der Königl. Preussischen Akademie der Wissenschaften, p. 24, 1848.
‡ Der Dysp, p. 23, pl. xxiii., fig. 1, 1861.
body may have been covered with shagreen, but in the specimens available for observation the skin was without scales or other protection. The spine was apparently one-fourth to one-fifth of the entire length of the fish; it was implanted in the occipital cartilage without articulation. The vertebral column was notochordal, more or less encircled by the bony extremities of the apophyses; ribs, short and rudimentary, were present, with the articulating extremity broad, and the opposite one pointed. Immediately behind the spine there originated a dorsal fin, which extended along the back to the caudal extremity. In addition to the fin rays and the spinous processes attached to the vertebral column, there were two series of interspinous bones. This arrangement extended to a short distance beyond the ventral fin. The smaller interspinous bones, surapophyses of Fritsch, next to the neurapophyses, then disappear, and the longer interspinous bones continue nearly to the caudal extremity of the body. A fin also extended along the ventral surface of the body, and joining the dorsal one formed a single-lobed tail.

Dr. Kner describes four or five gill arches, furnished with a few long teeth. The skull was of so soft and cartilaginous a nature that the orbits are obliterated, and no evidence is afforded of any segmentation of the covering of the skull. The constituents of the cranium and the jaws were recognized as consisting of cartilage filled with closely approximating ossicular centres. This enamel-like arrangement was compared by Beyrich to a species of mosaic. The upper jaws are stated to consist of maxillary bones, with pre-maxillaries attached, both provided with teeth.

The organs attached to the ventral fins, considered by Dr. Geinitz to have been suckers, were described by Dr. Kner as hooking organs similar to the claspers of sharks found at the present time, and this opinion be enforced by the observation that some of the fishes possessed these appendages and others did not; those possessing them being the male fishes, and those devoid of them being females.

Messrs. Hancock and Atthey found the teeth of Diplodus, associated with large patches of thick granular substance resembling shagreen, in the Coal Measures of Newsham and Cramlington, in Northumberland. This association led them to write:—"There can be little doubt that these shagreen-like patches are the remains of the skin of some large fish, and that the Diplodi are dermal tubercles in connexion with it, and analogous to the spinous tubercles of the Rays. At the same time it must be admitted that it is possible enough that the larger specimens may have clothed the lips or jaws with a spinous pavement resembling in arrangement the oral armature of the Rays or Cestracions." The authors describe the great variation in size and form of the so-called dermal tubercles, and recognize that the D. minutus, Ag., belongs to the same species as D. gibbosus. It is also

pointed out that the genera *Ditlodus, Aganodus, Pternodus,* and *Ochlodus,* described by Prof. Owen, are all referable to *Diplodus,* and had been established on varying examples, more or less fragmentary, of the teeth of that genus.*

A Paper was published by the writer in 1880,§ on the genus *Pleuracanthus,* Agass., in which several new forms of spines are described, principally derived from the cannel coal at Tingley, near Leeds, but also from the Staffordshire coal field and Lower Coal Measures of the West Riding of Yorkshire. These spines exhibited a number of intermediate forms between *Pleuracanthus levissimus,* Ag., and *Orthacanthus cylindricus,* Ag. The latter possesses two rows of denticles, which are situated comparatively close together on the median posterior surface, whilst the former has also two rows of denticles on the sides of the spine and as widely separated as it is possible that they could be. The examples described in the Paper “prove that the difference in the relative position of the two rows of denticles must either be of small generic importance or that many new genera will have to be formed for their accommodation. Almost every intermediate form between the two is now known; the denticles extend at every angle between the sides and back of the spine.” After careful consideration the opinion is enunciated that the several spines were borne by fishes having characters of a single generic type, and that they should consequently be included, under different specific determinations, in the genus *Pleuracanthus.* The *Diplodus* teeth have hitherto been found indeterminately associated with the spines of *Pleuracanthus, Xenacanthus,* and *Orthacanthus,* and afford additional evidence of their generic identity.

Professor E. D. Cope† has recorded the occurrence of more or less complete crania from the Permian beds of Texas. The specimens also include jaws and numerous teeth. The teeth are indistinguishable from *Diplodus gibbosus,* Ag., and *Diplodus compressus,* Newb. The latter is provisionally referred to a distinct genus, and styled *Didymodus.* Twelve more or less well-preserved crania were examined, one of which exhibited the jaws with teeth and a part of the cranium. The skull formed a continuous piece with distinct segmentation; it was elongated posteriorly and abbreviated anteriorly, the orbit occupying a position on the anterior third of the cranium with well-defined pre-orbital and post-orbital processes. The top of the muzzle is described as being “excavated by a fontanelle which does not extend posterior to a line connecting the pre-orbital processes.” The occipital elements form a wedge-shaped body divided medially by a suture with the apex forward. A second triangular bone is the parietal; its apex is concealed beneath the free extremity of the bone preceding it. On each side, between the occipital and parietal elements are bones which Professor Cope

considers may be the intercalare or pterotic. The element in front of the parietal
is the cartilaginous representative of the frontal, which terminates posteriorly in
two free processes. There are also “distinct paired membrane bones which
appear to represent the frontals in Ceratodus”; each is a flat, subresescent
supra-orbital plate, which has a concave supraciliary border. It is separated by a
considerable interval from its fellow on the opposite side. A fossa on its anterior
extremity is supposed to represent the anterior nostril.

The occipital bone includes ex-occipital and basi-occipital elements combined.
There is a prominent cup-shaped occipital condyle. The occipital extends only a
short distance on the inferior surface, and is attached directly and without
imbrication, to a continuous axial element which it is suggested is a combination of
the sphenoid and pre-sphenoid bones. The upper jaw, consisting of palatine and
pterygoid elements without division, was apparently articulated with the post-
orbital process of the cranium. The posterior border of the palato-pterygoid forms
a prominent rim descending to the mandible and forming a regular ginglymus,
the mandible bearing the cotylus. The mandible is robust; inferior edge thin
and incurving anteriorly. The superior border is regular, only rising a little in
the coronoid region corresponding with a concavity in the pterygoid region. A
portion of a hyo-mandibular bone is exposed.

These remarkable specimens constitute the first recorded discovery of the
skulls of Pleuracanthus, showing that they were divided by sutures into segments,
and this Prof. Cope considered was a sufficient reason for the institution of a new
order of the Elasmobranchii, which he names the Ichthyotomi.

A very interesting series of specimens, between twenty and thirty in number,
have been found by M. Fayol in the Coal Measures of Commentry, Allier, in
France. These were forwarded to M. Charles Brongniart, of the Museum of
Natural History, Paris, and have been described and figured as Pleuracanthus
Gaudryi, Brong.* They vary in length between 0·5 and 1·0 m., and the head
occupies about one-fifth the length of the fish. It is not possible, in any of the
specimens, to distinguish the pieces composing the head. The jaws are rounded
in front and furnished with small teeth along their borders. On one specimen
four grooves were distinguishable, probably representing the branchial arches.
The spine is straight, pointed, and on the upper part on each side is a row of
denticles, recurved towards the base of the spine, which most nearly approaches
P. Frosardi, Gaudry, and P. pulchellus, Davis. “Derrière l’aquillnon céphalique
se dressent de petits rayons réunis à lui par une membrane, formant ainsi une
nageoire que nous appellerons céphalique.” This fin is stated to be similar to that

4ième Livr. 1888, pls. 1.—vi., woodcuts 1—15.
of Cestracion, except that it is in a more advanced position. The dorsal fin extends the whole length of the back to the base of the caudal, equal to three-fifths the entire length of the fish. The dorsal fin, as previously shown by Kner* in specimens from Klein-Neundorf, is supported by a complicated series of rays. The bony neurapophyses are broad at the base, forked above; to each branch of the fork is attached a short ray, the surapophysial, to which is attached the interspinous ray supporting the fin-ray. The caudal fin encircles the posterior extremity of the body. Its upper lobe is supported by a series of rays similar to those of the dorsal fin, except that the surapophyses are absent; and nearer the extremity the interspinous bones also disappear. The hæmaphyses are more robust and longer than the neurapophyses, but have no rays attached: the first five or six haemal arches are composed of two parts, united at their base and eneircling the notochord. Further back they diminish in length and lose this character. The scapular and clavicular elements of the shoulder girdle are cemented into one piece, and their junction forms the point of attachment of the pectoral fin. The central support of the fin consists of a jointed pterygium, the elements composing it gradually diminishing in size, the last being long and filiform. From the external margin of this axis spring the fin-rays, varying in length, and articulated. On the internal margin there is a smaller number of rays, not articulated. M. Charles Brongniart considers the pectoral fin of Pleuracanthus to exhibit characteristics intermediate between the biserial articulated pterygium of Ceratodus and the pectoral fin of Acanthias vulgaris. The pelvic arch has a general resemblance to the pectoral, but it is smaller. Each fin is attached to a moiety of the arch, similar in form and comparable in parts to the scapula and clavicle of the pectoral arch. The median axis is composed of cylindrical cartilaginous elements placed end to end, but diminishing little, if any, in size, and the fin-rays are attached only to the external margin. The axis, instead of being straight, as in the pectoral fin, is curved and forms the arc of a circle. To the extremity of each axis is attached a piece which can only be regarded as an appendix to the genital organs, similar to the claspers in the sharks, rays, and chimera. These are found only on the male fishes. In the female the pelvic fins are feebler, and the median axis terminates within the membrane of the fin.

There are two anal fins which have remarkable peculiarities. They are lobate, rounded, contracted at the base, enlarged in the middle, and again contracted towards the extremity. Both fins are similarly constructed. The hæmaphyses to which they are attached are shorter and more inclined than those of the caudal region; they are truncated instead of pointed, and three

in number. The first and second have attached to them interspinous bones and fin-rays. The third is larger, broad at the two extremities, slightly curved, and towards the middle, on the concave side, is a sort of apophyse, to which is attached an interspinous ray and a fin-ray; its extremity supports a shorter and broader ossicle. The latter affords attachment to three elements—first, a long and pointed ray, extending backwards, and two ossicles, of which the posterior one supports two short ossicles and fin-rays, and the anterior one ossicle and one fin-ray. "Ces nageoires anales présentent donc une structure très complexe et rappellent par leur disposition de véritables membres."*

Mr. A. Smith Woodward has pointed out† that the teeth of Didymodus are generically indistinguishable from those of Diplodus, and he has included the two in the genus Pleuraeanthus. This author is also convinced that the presence of membrane bones‡ in the skulls of the Texas specimens is more than problematical, and founded on a misconception. Reporting on a recent visit to Professor Cope's collection of fish and other fossil remains at Philadelphia, Mr. Woodward says§ the skulls of the Ichthyotomous Elasmobranch "Didymodus" certainly exhibit with distinctness the extraordinary fissuring of the chondro-cranium, though in the strict sense of the term it is scarcely accurate to name the segmented parts "bones."

During the years 1889 and 1890 Dr. Anton Fritsch of Prague published two parts of his important work on the gas coal of Bohemia,‖ which are almost entirely occupied with the genus Pleuraeanthus, as now defined. Dr. Fritsch prefers to regard Pleuraeanthus, Xenacanthus, and Orthacanthus as distinct and independent genera, and bases his diagnosis upon the teeth, spines, and denticular appendages of the gill arches, taken in conjunction with the construction of the archipterygium and fin-rays of the pectoral fins. Four species of Orthacanthus are described, viz. O. Bohemicus, Fr.; O. Kounovienis, Fr.; O. pinquin, Fr.; O. plicatus, Fr.; and a fifth, O. Senkenbergianus, Fr., is from Lebach. The remains are of a more or less fragmentary character. The remains of Pleuraeanthus and Xenacanthus are much more perfect, and the study of them has enabled Dr. Fritsch to add considerably to our knowledge of the Pleuraeanths. Only one species of Xenacanthus is recognized, the type X. Decheni, Goldf., whilst there are four species of Pleuraeanthus from the Bohemian formations described, they are, P. ovalis, Fr.; P. Œlbergensis, Fr.; P. carinatus, Fr.; and P. parallellus, Fr. The denticles on the spines of both genera are lateral, but the cavity is said to be smaller in Pleuraeanthus than in Xenacanthus, and there is in the former an external median groove on the posterior

surface. The pectoral fins do not differ greatly in *Orthacanthus* and *Pleuracanthus*, but in *Xenacanthus* the fin is shorter proportionately to the others, and there are dermal fin-rays, which the others do not possess. The skull is described as consisting of a continuous cartilage, without segmentation or membrane ossification, and there are seven gill-arches; the shoulder girdle is more or less similar to a gill-arch. The spine is attached to the posterior portion of the cranium and is not attached to a fin. The cartilaginous skeleton exhibits a granular calcification. The vertebral column is notochordal, the neural and haemal arches are largely ossified, and in two genera there are intercalary cartilages. The pelvic fins are provided with claspers in nature male fishes. The form and structure of the anal fins is fully elucidated. The work is illustrated with numerous figures, in addition to the plates, mostly taken from galvanoplastic models of the original specimens.


Hitherto the descriptions of the fossil remains of this genus from the Coal Measures of Great Britain have been confined to examples of the spines variously considered as those of *Pleuracanthus* or *Orthacanthus* and teeth named *Diplodus*. The discovery of a number of isolated spines in the Coal Measures of the West Riding of Yorkshire,* exhibiting a very varied series of forms, has led to the conclusion that the spines named by Agassiz, as above, can only be regarded as modifications of the same genus. *Diplodus* teeth have been found associated almost indiscriminately with both forms of spine, and render the possibility of any distinction into genera still more remote. In other instances the teeth

---

found associated in a single jaw are so divergent in form that specific distinction of isolated examples becomes quite problematical. The spines certainly offer more persistent and better defined characters than the teeth. A comparison of the figures of the teeth in the fine series of specimens it is now proposed to describe from the Newcastle coal field will confirm this view. Had all the teeth been obtained as individual specimens they might reasonably have served for description as different species. Notwithstanding these difficulties, the occurrence of numbers of apparently well-defined and persistent forms, sometimes found only in one locality and stratum, and in others characteristic of several localities, renders necessary their description as separate species.

In addition to the isolated specimens of spines and teeth there have been found masses of shagreen, with an occasional well-preserved archipterygial fin, or single specimens of spinous or interspinous processes, in the Coal Measures of the West Riding of Yorkshire; but the most valuable and interesting series of specimens has been discovered in the Lowmain coal seam at Newsham, in Northumberland, and is contained in the Atthey collection, recently purchased by Lady Armstrong, and placed in the museum at Newcastle-on-Tyne. From the same locality, a second collection, containing most remarkable examples, has been acquired by Mr. William Dinning, of Newcastle. Examples from both collections are described in the following pages. The fishes varied very much in size, from an example measuring nearly half a metre across the head and with a possible length of three or four metres, to a head represented by the exquisitely preserved cranium in the possession of Mr. Dinning, which has a diameter of only one-tenth of a metre. The latter specimen is the only one found on this side the Atlantic exhibiting a cranium in which the several elements are separated by sutures. The beautiful series of examples found in Bohemia and described by Dr. Fritsch; or those equally well, or perhaps better, preserved found at Commentry, in France, and described by M. Chas. Brongniart, exhibit the cranium only as a mass of cartilage without segmentation. The fossil remains described by Professor Cope as "Didymodus," obtained from the Permian beds of Texas, possessed crania which showed the component parts forming a continuum displaying distinct segments. The example in the collection of Mr. Dinning exhibits the surface configuration of the cranium with great clearness.

The upper and lower jaws are exhibited, in relative position to each other, in a very fine specimen at the museum at Newcastle. The specimen was excavated and developed by the late Mr. Atthey. On one side of the slab the two lower jaws are preserved, with large cranial plates lying near; and on the opposite side the upper jaws are exposed, with numerous teeth, as well as the reverse sides of the plates exhibited with the lower jaws. This specimen probably
indicates the largest example of the genus known; and compared with the complete examples obtained from the strata of Bohemia or Comenentry, the Newsham fish must have been between three and four metres in length.

The lower jaws are 0·15 m. in length, the posterior part of the jaw is 0·11 m. in height, and diminishes to about half that amount anteriorly. As in the lower jaw exhibited in Plate lxv., its posterior portion appears to have had centres of ossification bounded by more or less angular borders (fig. 1a), and giving it the appearance of being composed of a series of plates. The left jaw (fig. 1b) is in a normal position, the right has been to some extent flattened out, which gives a more largely expanded surface than it probably possessed in a natural state. The outer borders of the two lower jaws correspond in position with those of the upper jaws exhibited on the opposite side of the slab, and the latter have impressed their form on the former, giving them the appearance of having a thicker border than they really possess, but for which they would no doubt have got credit had the specimen been less perfect. Numerous teeth are scattered between and about the jaws. The right ramus of the lower jaw is somewhat broken, as shown in the figure, but the depression of the surface (fig. 1a) may indicate the position where articulation has been. A thickening of the bone appears to show that the articulating surface was in its immediate vicinity.

To the right of the left mandible (fig. 1b) there are two or more large cranial plates. The one marked (fig. 1d) is 0·20 m. in length and 0·13 m. in breadth; it has a convex outer margin corresponding in curvature with the inner one which is concave. Both ends of the plate were probably attached to other bones; the outer convex margin is thicker and stronger than the other parts. The form of this plate is similar to the one marked (a) in Mr. Dinning's specimen (Pl. lxxv., fig. 2) which occupied a position on the margin of the cranium in a line with the occipital plates. Another large osseous plate (fig. 1e) occupies an area in advance of the one described. The mass is 0·24 in length, and may consist either of a single plate or more probably of two; it is more rectangular than the one mentioned before, and probably extended in front of it towards the anterior part of the skull.

The opposite side of the specimen is no less interesting. The palato-pterigoid constituting the upper jaws are exposed as well as the cranial plates marked d and e of the figures of the other side. The outer margin of the jaws is nearly circular (Pl. lxxvi.), and from right to left the diameter is 0·43 m. A line drawn from the symphysis of the rami to the posterior extremities of the jaws is 0·44 m. in length. The outer margin of the jaws is thicker than the remaining portion, and as previously observed has impressed its form on the opposing lower jaws. The posterior extremity of the right jaw, which is perfectly exposed, is narrow, the inner margin being concave and the diameter 0·07 m. at a distance of 0·07 m. from the end. From that point it rapidly expands and joins up to the opposing
jaw with a long straight suture extending along the median line of the palate. Its broadest part is 0.14 m. The inner margin is comparatively thick, but much less so than the outer margin; the intermediate area is apparently thin, but of the same chondroid or granular structure as the other portions, the usual osseous centres being abundantly intermixed with the cartilaginous base.

The wide expansion of the palato-pterygoid bone over the palate is remarkable. The researches of Dr. Anton Fritsch have shown that the bone in the palatine region extends high up the side of the head, diminishing anteriorly and extending to the snout in a more or less attenuated form. This magnificent specimen exhibits a lateral expansion from the anterior portion of the jaws, so as to form a pair of osseous plates extending to the median line of the palate and there joining together. In the German specimens of *Pleuraecanthus* (*Xenacanthus*) Dr. Kner considered that the upper jaw was divided into maxillary and premaxillary, but in this specimen there is no evidence of this unless the elements at the nasal extremity can be so construed. The Texas example, described by Professor Cope, showed the upper jaw to consist of a single bone on each side the palato-pterygoid. This view is also supported by the specimens described by Dr. Fritsch.

The large expansion of the palato-pterygoid over the palatal area of the mouth in this specimen does not extend to the anterior extremity of the jaws, but a triangular area starting at a point where the two rami are most anteriorly in juxtaposition, 0.08 m. from the nasal extremity, is occupied by a number of smaller semi-osseous pieces mixed with numerous teeth; these apparently completed the anterior portion of the wide rounded snout, and probably represent the pre-maxillary. There is at the anterior termination of the palato-pterygoid a thickened concave margin which has apparently served for attachment to the pieces composing the snout. The several parts, however, are not so well preserved as to enable a reproduction of the natural arrangement to be made (Pl. lxv., fig. 1cc). This peculiarity is indicated in the specimen described by Dr. Jordan in the Neues Jahrbuch in 1849, and afterwards figured by Dr. R. Kner,* in which the under surfaces of the upper jaws are exhibited, separated by a distinct interval at the anterior extremity.

The teeth are numerous and vary considerably in form. The average length is 0.015 from the base to the extremity of the denticles. The form may have borne some relationship to the position the teeth occupied in the mouth, but in this specimen, as in nearly all the others, the teeth are scattered in indiscriminate confusion over the slab, and only a very rough estimate can be made as to their original position. There are a few teeth, however, which appear to be in their proper places attached to the anterior portions of the jaws. They are smaller.

than the majority, which probably occupied a posterior position. The lateral
denticles are comparatively strong, and they are considerably bent inwards; the
median denticle is shorter and thicker than that of the teeth further back
(Pl. lxxv., fig. 2). From an examination of the examples figured it will be observed
that they offer a considerable variation in form, and taken independently would
probably have been considered to represent fishes of distinct species.

The shoulder-girdle, together with bony masses of the branchial arches, are pre-
served on a slab obtained from the roof of the Lowmain coal seam near Newcastle,
now in the collection of W. Dinning, Esq., of that city. The bones of the scapular
arch to which the pectoral fins were attached (Pl. lxxvii., fig. 1 a, b) occupy approxi-
mately a natural position. They are large, well-developed chondroid structures.
The scapular elements enumerated by Dr. Anton Fritsch* appear in this specimen to
be fused into one piece, no lines of demarcation being visible. The central portion
of the specimen is occupied by portions of the branchial arches, those on the left
side (c, c₁, c₂, c₃, c₄) being five in number, whilst on the right only four can be dis-
tinguished (d, d₁, d₂, d₃). A large and massive osseous element (e), partly projecting
and partly under the right scapular arch, is probably the hyo-mandibular. Scattered
over the slab are a number of the small stemmatoid ossicles (fig. 1 g) previously
described, which have been separated from the branchial arches. A peculiar bone
of a tripartite character occupies a position behind those mentioned above. It has
a length of 0·025 m. along its median axis, extending antero-posteriorly (fig. 1 f),
at a distance of about one-fourth its length from the posterior extremity; a branch
extends from each side, 0·011 m. in length; 0·005 in diameter at the base of
attachment, and diminishing to a point at the distal extremity. The derivation of
this bone is not quite clear, but it may have been attached to the occipital region
of the skull, and served as a base for the attachment of the cephalic spine.

Dr. Anton Fritsch describes the genera *Pleuracanthus* and *Xenacanthus* as
being possessed of seven gill arches.† The principal evidence is afforded by a
specimen of *Xenacanthus Decheni*, Goldf., from the limestone of Oelberg, near
Braunau. The specimens of *Pleuracanthus* are from the gas coal of Tremosa, near
Pilsen, and are more or less imperfect. Dr. Fritsch intimates that the true defi-
nition of the gill-arches is very difficult, and so far as the *Pleuracanthus* is con-
cerned he should not hold the evidence sufficient were it not for the proof that
the allied genus *Xenacanthus* could be shown to have had seven gill-arches on each
side. The first arch is weak; the second to the fourth are similarly strong and
longer; the fifth is shorter; the sixth still shorter; and the seventh is much thicker

* Fauna der Gaskohle, vol. iii., pt. i., p. 41, fig. 240 (woodcut).
† Fauna der Gaskohle, vol. iii., pt. i., p. 8, pl. xcix., fig. 3; pl. xciv., fig. 1; and p. 25, pl. xcvi.,
fig. 1, woodcuta 193 and 215.
and stronger, with a rough surface for the attachment of gill-rakers. M. Brongniart * states that one of the specimens he described exhibited four grooves on the surface, which probably represented the branchial arches. "Ce qui vient corroborer cette opinion, c'est qu'il existe à leur base de petites rayons, visible sur tous les exam- plaires et qui assurément ne sont autre chose que la charpente des branchies." In the example now described the evidence appears to be with the French specimens, a matter of some importance in relation to the classification of the genus.

A remarkable specimen in the collection of W. Dinning, Esq., of Newcastle, also from the Lowmain coal seam, is represented on Plate LXVII., fig. 2. It exhibits the bones comprising the upper surface of the cranium. The specimen has been slightly crushed, and some of the lateral bones are displaced, as shown in the figure. This specimen, along with others in his collection, has been most carefully extricated from the matrix, and is a model of what may be done by skilful and painstaking application. The bones of the median part of the skull are undisturbed, whilst those occupying positions on each side have been subject to lateral pressure and to some extent overlap each other. The bones, if they may be so termed, or plates, are all of nearly uniform thickness, 0.003 m., and where one has been forced over another, the plates are bent, and have received the impress of the one above or below respectively, which appears to indicate very clearly, that whilst the plates were sufficiently osseous to maintain their outward shape, they were so plastic that their surface conformed readily to that of a contiguous substance.

The central portion of the cranium is formed by a pair of subtriangular plates joined by a straight median suture; they are broad posteriorly, the anterior margins being equal to half the breadth of the posterior ones; these probably represent the parieto-frontal bones (a). Behind these the occipital (b) occupies a median position. At the junction of the frontals with the occipital there is a small foramen; and behind, the under surface is strengthened by a large ridge, more or less circular, which probably afforded an attachment for the cephalic spine (Pl. LXVII., fig. 3). On each side the occipital, and attached to it and to the pos- terior margins of the frontals, are a pair of plates (c) almost equal in size to the occipitals; and beyond these again, completing the posterior portion of the cranium, are a pair of large plates exceeding in size either of the intermediate ones. The plate to the right of the specimen is in its natural position; the one on the opposite side is squeezed forward and covers some of the smaller bones forming the left portion of the cranium and also a part of the left frontal (fig. 2 d). On each side the frontals, and parallel with their margins, are two smaller plates (e, f); outside the anterior ones the orbits probably existed, but in this specimen

the lateral plates are squeezed towards the middle, so that the orbits are more a matter of inference than certainty. Outside these again, and forming the lateral margin of the cranium on each side, are two plates (g and h) represented approximately in their natural position in figure 2 a, and in figure 2 by the same letters. Both the plates have been displaced, the anterior portion of each being pressed under the preceding one. The form of each, however, is clearly seen on the under surface of the specimen. Anterior to the frontals, and occupying a median position, is a small hexagonal plate (x). To it are attached, besides the frontals, the inner lateral plates (f), and in front, extending towards the snout, a pair of large semi-rhombooidal plates (i, i). The posterior margins of these are joined to the anterior margins of both the inner and outer lateral plates.

The cranium thus constituted is circular in front, expanding backwards and forming a wide extension in the occipital region. The width across the latter is about 0·10 m., and the distance from the anterior extremity of the snout to the outer margin of the occipital plate is 0·07 m.

The arrangement of the teeth is exhibited very clearly in a specimen in the collection of Mr. George Wild, from the Thin Bed Coal at Burnley in Lancashire (Pl. lxviii., fig. 4). The teeth are comparatively small, their total length being 0·007 m., of which the basal part occupies 0·002 m., and the two principal cusps 0·005 m. The cusps are long, slender, divergent; between the two, the median cusp ascends; it is fully half the length of the principal ones, very graceful and slender. Posteriorly at the base of the two principal cones there is a large and prominent circular bulb; the base of the tooth is antero-posteriorly broader than it is between the two sides. More than fifty teeth are preserved in this slab, and appear to be derived from both the upper and lower jaws. Two or three rows are preserved in sequence. In one row there are six teeth, and in another there are five (fig. 4). These are probably from the lower jaw. The opposing teeth have the cusps pointing in the opposite direction and towards those of the upturned ones of the lower jaw; they are not in rows, but more or less disturbed; they are smaller than the others, and the median cusp is longer in proportion to the lateral ones, otherwise the teeth possess similar characters. They are of the form described by Mr. A. Smith Woodward as Diplodus tenuis, and as this is now shown to be associated with Pleuracanthus (Diplodus) gibbosus, the Burnley specimens must also be included. Though in this specimen there is not any appreciable variation in form, this may be due to the small portion of the whole mouth which is preserved.

The specimen (Pl. lxxix.) is from the Attley collection, presented to the Newcastle Museum by Lady Armstrong, and exhibits the right ramus of the lower jaws (a) with a portion of the left ramus connected to it at the symphysial extremity (b). The length of the jaws is 0·36 m. The greatest
depth is near the posterior extremity where the jaw is 0·08 m., thence it becomes less towards the symphysis, near which the jaw has a depth of 0·03 m. Posteriorly the extremity consists of a concave articulatory surface (a') by which it was attached to the palato-pterygoid. The substance of the jaw is crushed, and appears to indicate that it was not sufficiently strong to resist the pressure of the superincumbent matter. At the same time the fractured surfaces show that it was by no means elastic. The anterior extremity was probably of a firmer or more osseous consistence than the bulk of the jaw behind; but from the symphysis backwards the lower part of the jaw had a similar texture, as indicated by the compact structure of the fractured surfaces. The dentary surface was also of a firmly osseous substance, but the part of the mandible between the two has the appearance of having had a thin osseous covering, protecting an internal mass of more or less cartilaginous matter. The surface of the bone is rugose, and where fractures have exhibited the internal structure its chondroid character is clearly seen, the osseous centres presenting very much the appearance of a piece of oolitic limestone, except that the colour is black. The dentary surface is hidden by a large number of teeth; the latter have been displaced and are heaped together in a confused mass (c, c). The left mandible is in a great part hidden by the teeth, the anterior portion (b) is exposed compressed behind the right one. The lower jaws appear to have extended beyond the upper one, but probably not to the extent indicated by the anterior extremity of the upper jaw (d).

The teeth present considerable variety of forms; they are, however, so indiscriminately mixed that it is only possible to roughly estimate the position they occupied in the jaws, and the difference in form due to their location. Besides the typical examples hitherto regarded as Diplodus gibbosus, Ag., others with more slenderly elongated cusps have been recognized by Mr. A. Smith Woodward as identical with the teeth he has described as Diplodus tenus.* Another form presents very much the appearance of Pleuracanthus (Triodus) sessilis described by Dr. Jordan;† and the typical forms selected by Dr. Anton Fritsch‡ as representing the three genera, Orthacanthus, Pleuracanthus, and Xenacanthus, may all be found in the teeth from the jaws of this specimen (Pl. lxvi.).

On the lower part of the slab are two series of bones which are displaced, and probably represent the branchial arches. They each consist of four or five osseous elements connected together and having a semicircular arrangement. The bones are similar in character to those of the jaws, consisting of closely impacted

---

* Catalogue of the Fossil Fishes in the British Museum, pt. i., p. 11, pl. vi., figs. 2-4.
† Neues Jahrb., p. 843. 1849.
osseous centres in a cartilaginous framework. They are larger at the proximal end of the series and diminish in diameter towards the opposite one (cf. i., ii., iii., iv.). They may be compared with the specimens figured by Dr. Fritsch of the branchial arches of Orthacanthus Kononoviensis, Fr., a large species comparable with this one, in which the branchial arches are composed of a series of four or five separate semi-osseous parts.*

Separated from, but near the branchial arches, are a number of small denticulated ossicles, which were probably attached to the gill-arches. They consist of a series of small, sharp denticles, attached to a broad base. The arrangement of the denticles varies in nearly every example. Those represented on Pl. lxx., figs. 2, 3, are from the slab now described; others have been found in the Coal Measures of Staffordshire, Lancashire, and Yorkshire.

The example represented by fig. 4 was found associated with the remains of Pleuracanthus, near Wigan; it has seven irregularly disposed denticles attached to a more or less triangular base. The denticles are elongated, smooth, and pointed. Mr. G. Wild has examples which he has collected from the Middle Coal Measures of Lancashire, one of which, with 16 or 17 prongs, is represented by fig. 5.

Mr. John Ward has found a considerable number of similar objects in the Ragmine Ironstone Shale, at Fenton in Staffordshire, associated with teeth and other remains of Pleuracanthus (figs. 6–10). They exhibit a great variety in the form and arrangement of the denticles, but notwithstanding the difference in the number of the denticles and the varied manner in which they are attached to the base, there is a general similarity of construction which appears to indicate uniformity of purpose.

Similar objects were found in the fish-bed of the Upper Burlington Limestone of the Lower Carboniferous Rocks of America. Messrs. St. John and Worthen,† who described the remains, considered them of so anomalous and withal variable character as seemingly to indicate representatives of several distinct though closely-allied generic groups. Subsequently they were regarded as the teeth of a single genus, which was named Stemmatodus, and the so-considered teeth were divided into several species. They were supposed to have occupied the tongue or back part of the mouth of fish similar to Diptherus or Ceratodus. Mr. A. Smith Woodward‡ regards the specimens described by Messrs. St. John and Worthen, as well as those from Fenton in Staffordshire, as the dermal tubercles of some of the Elasmobranchs, and this opinion is accepted by Mr. John Ward.§

Dr. Anton Fritsch* discovered and described a number of similarly denticulated fossil remains attached to the gill-arches of Pleuracanths in the Gaskohle of Bohemia. A comparison of the figures of the specimens described by Dr. Fritsch with those now figured from the English Coal Measures will at once demonstrate the identity of their origin and purpose.

The specimen from the Lowmain coal seam at Newsham, represented on Pl. lxx., is the head of a large specimen, much crushed and displaced, but exhibiting some interesting features. The mass preserved on the slab is 0·37 m. from front to back, and 0·27 m. across the head. A large spine of *Pleuracanthus lavoissimus*, Ag., extends from the centre of the slab, apparently the middle of the head; it is 0·17 m. in length, but the anterior part of the spine is absent. The base of the spine, extending to the part on which the denticles are present, is about 0·14 m. in length; and had the whole of the spine been preserved, a comparison of this with other perfectly preserved specimens, indicates a length of 0·22 m. The base of the spine has a diameter of 0·013 m., and higher, where the denticulated surface begins, the diameter is 0·01 m. The surface of the spine has the striated appearance characteristic of the species, and the denticles are similar to those already described as *P. lavoissimus*. As to the manner in which the spine was attached to the cranium, this specimen does not give much information; there are a number of semi-osseous structures in immediate proximity to the base of the spine, and to these it may probably have been attached, but the method of its attachment is not shown.

Immediately below, and almost parallel with the spine, there extends the right ramus of the lower jaw, crowded with teeth; it originally extended beyond the margin of the slab, but is imperfect. The teeth are similar to those exhibited on Pl. lxxix., and are those known as *Diplodus gibbosus*, Ag. The vertical arrangement on the alveolar surface is well shown; there were four teeth, possibly more, in each row, which lie closely parallel to each other. Nineteen or twenty vertical rows of teeth may be distinguished, and the extremity of the jaw being absent the total number would be larger. Besides the teeth of this jaw, there are numerous others scattered over the slab intermingled with masses of bony structure representing the semi-osseous cranial plates. The latter are too much disturbed to allow their relative natural position to be made out.

The occurrence of the spine, *Pleuracanthus lavoissimus*, Ag., and the teeth, *Diplodus gibbosus*, Ag., on this specimen is of importance, because it removes any doubt as to the identity of the series of specimens obtained from the Lowmain coal seam.

The specimen figured on Pl. lxxi. is from the collection of W. Dinning, Esq.,

of Newcastle-on-Tyne. It exhibits a part of the body and the posterior portion of the head, with a number of teeth. Several detached cranial plates (b, b) and a large bone (a), which probably represents the lower jaw, are present. Associated with these are many spinous and interspinous bones. The latter are long, straight, and slender; of a dense bony structure, apparently similar to that of the spines. The spinous apophyses are much dilated at the proximal extremity, which was attached to the sheath of the notochord (c, c). The teeth are those of the so named Diplodus gibbosus, medium size; the lateral prongs are slender and attenuated, and the median denticle is also comparatively long.

The long interspinous rays are frequently met with in the coal fields where remains of Pleuracanthus occur. On Pl. lxxi. two interspinous rays are figured, natural size; one measuring 0·12 m. and the other 0·125 m. Along with these were found examples of the surapophyses, three of which are represented on the same Plate (fig. 4). They vary from 0·01 to 0·015 m. in length.

A specimen exhibiting the left pectoral fin is represented on Pl. lxv., fig. 2. The part preserved is 0·1 m. in length, and comprises a portion of the pterygium, with a mass of fin-rays attached to its outer border, and a smaller series on its inner one. The constitution of the central axis is not well preserved. The outer series of fin-rays number in this specimen twenty-two or twenty-three; the longest are 0·09 m. in length, and each is divided into about ten parts articulated together. The articulated segments are longest in the median part of the ray, shorter towards the axis, and pointed at the distal extremity; they have an average diameter of 0·002 m. The rays are semi-osseous, and have the usual granular appearance. The fin-rays springing from the inner surface are shorter and more slender; they are little more than half the diameter of those on the opposite one.

The form and constitution of this fin differ considerably from those described by M. Brongniart* and Dr. Fritsch.† There are a larger number of rays, and each is divided by a greater number of articulations. The rays attached to the segments of the pterygium, near the basal extremity, are proportionately longer than those of the French or Bohemian fishes.

The specimen figured is from the cannel coal at Tingley, in the West Riding of Yorkshire, and is in the collection of the writer.

---

* Études terr. heuil. Commentry, p. 25, pl. iv.
Pleuracanthus lævissimus, Agassiz.

(Pl. lxxii., figs. 1–9.)

I.—Spines.


Pleuracanthus planus. Agassiz, L., 1843, tom. cit., p. 177 (name only).


I.—Pleuracanthidae.

II.—Teeth.

*Diplodus gibbosus*, Agassiz.


*Diplodus gibbosus*, . . . Agassiz, L., 1843, "Poiss. foss.," vol. iii., p. 204, pl. xxii. b, fig. 1 (non figs. 2–5).


*Dittodus divergens*, . . . Owen, R., 1867, tom. cit., p. 334, pl. II.


*Diplodus tenue*, A. S. Woodward.


III.—Gillrakers.

Stemmatodus, St. John & Worthen.

Stemmatodus, . . Woodward & Sherborn, 1890, "Brit. Foss. Verteb.,” p. 188.

The teeth of *Pleuracanthus levissimus*, Ag., vary greatly in form; there are two principal cones, circular, or more or less compressed, with or without lateral cutting edges, sometimes striated. The cones are divergent, and frequently exhibit a slightly sygmoideal curvature. Between the two outer denticles is a smaller intermediate one, which may be short and compressed or comparatively long and slender. On the posterior surface behind the smaller intermediate denticles is a "button," which forms the seat on which the anterior part of the base of the succeeding tooth rested. The "button" is of irregular size, sometimes prominent, at others scarcely discernible, which is probably due to the different relative positions occupied by the teeth. Base broad, extending backwards, inferior surface more or less flattened.

The spines of *Pleuracanthus levissimus* are straight, broad at the base, and tapering upwards to a more or less pointed apex; compressed antero-posteriorly,
I.—Pleuracanthidae.

but towards the distal extremity circular in section; surface smooth. Double row of reflexed, acuminate denticles, one on each lateral margin and extending along two-thirds the length of the spine. An internal cavity extends from the base upwards. Towards the distal end the internal cavity is small, lower it is large, and the walls of the spine are thin; they are frequently crushed. The base of the spine, when preserved, is contracted at the extremity, and the portion embedded in the integuments was not proportionately large. The large groove stated by M. Agassiz* to extend along the inferior surface of the spine does not always exist in the specimens examined; the appearance may have been due to crushing. The only other record of a similar groove is in the spines of Pleuracanthus parallelus, Fr.,† from the gas-coal of Nyran, in Bohemia.

The base of the spine represented on Pl. lxxii., fig. 1, is worthy of note. It is widely and rapidly expanded, which is probably, in part at any rate, due to crushing; but this will not account for the whole of the expansion.

The spines of this species vary considerably in size; the largest are about 0·3 m. in length; one specimen from Dalkeith, in the British Museum, has a length of 0·35 m. (Pl. lxxii., fig. 2). The specimen from Dudley, figured by Agassiz, is 0·22 m.; ‡ others from the Lower and Middle Coal Measures of the West Riding of Yorkshire attain the same length, whilst the graceful and well-preserved examples from the Staffordshire coal field are mostly about 0·15 m. in length.

Associated with the larger spines of the cannel coal, in the Middle Coal Measures of the West Riding at Tingley, there are a number of small spines, which have been previously described as Pleuracanthus pulchellus §; they are generally the same length, about, 0·04 or 0·05 m. Since describing these exquisitely beautiful little spines, when it was suspected that they might be the spines of immature fishes of P. levissimus, the discovery of other examples has led to the conviction that such is their proper location, and that the difference in the number of lateral denticles, there being twenty on each side of the small examples against fifty in the large ones, may be due to the respective ages of the two, and increased growth of denticles as the spine has matured. The small imperfect spine named, but not described, by Agassiz,|| Pleuracanthus planus, originally in the collection of Sir Philip Egerton, and now in the British Museum, is about half-an-inch in length, the basal end absent; the exposed surface is smooth and flat, and six or seven strong denticles extend along each lateral margin. It is recorded as coming from

* Poiss. foss., vol. iii., p. 66, pl. xlv., fig. 5.
† Fauna der Gaskohle und der Kalksteine der Permformation Böhmens, Band iii., Heft. 1, pls. xci. and xciv.
‡ Poiss. foss., vol. iii., pl. xlv., fig. 6.

TRANS. ROY. DUR. SOC., N.S. VOL. IV., PART XIV.
Leeds, and was doubtless from the same locality as those mentioned above, and with them, may be included in this species.

The specimens described by Dr. R. H. Traquair* as Pleuracanthus elegans bear a close resemblance to the small spines from Tingley, originally described as a separate species but now included in Pleuracanthus lavissimus. The form, size, and number of lateral denticles is almost identical with the Tingley specimens, and if the latter are the young examples of this species, there can be little difficulty in assigning the small spine described by Dr. Traquair to this species also. The type is described as two and a-half inches in length, from the Blackband Ironstone of Borough Lee, near Edinburgh, and in the collection of R. Kidston, Esq., of Stirling.

The spines of Pleuracanthus lavissimus, Ag., from the cannel coal at Tingley are almost cylindrical in section as compared with those from the Fenton and Longton localities in Staffordshire. The latter are compressed antero-posteriorly, and oval in section; the spines from the Lowmain Seam near Newcastle are similar to those from Staffordshire. The lateral denticles on the Yorkshire specimens are larger and more widely separated than those of the other localities named (see Pl. lxxii., fig. 3). The number of denticles on the spines from the several localities offers considerable variety. The specimens found at Tingley, at Fenton, and the one from Newsham, represented by fig. 6 have between fifty-five and sixty denticles on each side, whilst the specimen, fig. 7, from the same locality, has only thirty-two, and the one from Shattleston, fig. 8, near Glasgow, has forty on each margin. The smallest examples, about two inches in length, average about eighteen or twenty on each side. Presuming that all these specimens are of one species, it would appear that the number of denticles increases with the age and size of the spine.

The occurrence of a large number of species represented by an abundance of specimens of each in the cannel coal of the West Riding of Yorkshire† appears to indicate that Pleuracanthus flourished and attained its greatest numerical development in fresh water. The cannel coal extends over a considerable area, in patches two or three miles in diameter, thickest in the centre and thinning off towards the edges, proving that it was accumulated in a series of lakes or lagoon-like depressions. The coal is a very pure carbonaceous substance with only 2 or 3 per cent. of earthy matter, and attains a maximum thickness of about two feet. To accumulate this large mass from the gradual decay of the leaves and spores shed by the plants growing in or about the lagoons would take a long time, and indicates a period of great quiet. Occasionally a stream ran through the lagoons bearing fine mud, and the latter settled along with the vegetable matter, and together

produced an impure coal, locally termed "hubb." The fish-remains are found indiscriminately in the pure cannel and the hubb, and associated with them are myriads of Unios and fresh-water shells. The latter probably served as food for the Pleuracanths, whilst the Coelacanths, which also existed in very large numbers, were probably vegetable feeders. Large spines of *Pleuracanthus* and *Gyracanthus* are not uncommon, and there can be no doubt that these sharks existed in the same lagoons and preyed on the smaller fish; the strong, sharply-pointed barbs with their lateral recurved rows of hooklets of the Pleuracanths would serve as an admirable defence against their more powerful adversaries.

A peculiar and abnormal specimen of *P. leviissimus* was found by Mr. George Wild, of Bardsley, in the shale forming the roof of the coal at the Arley Mine, Burnley. The specimen is imperfect. The part preserved is 0·105 m. in length, and consists of the middle part of a spine. The base and the point are wanting; the spine is oval in section, and denticles extend along each lateral margin as in the typical examples of the species. This one differs, however, from the types in several particulars. On one side of the spine there are three rows of denticles instead of one (Pl. lxxii., fig. 4), and on the opposite side there are two rows in one part of its length, whilst on the remainder there is only a single row. The latter margin is free from denticles for a distance of 0·045 m. from the basal end; whilst the margin with three rows extends the whole length of the existing part of the spine. In the shorter row there are twenty-one denticles on the median lateral line, and from the fourth to the tenth denticle the row is double (fig. 5). The denticles are strong and broad at the base; the apex curved backwards; and a groove extends along their base parallel with the length of the spine. There are thirty-three denticles in the median row on the opposite side, flanked on the one side by thirty-two denticles, smaller but of similar form, and on the other by twenty-three denticles extending from the basal end, but disappearing towards the distal extremity. The structure of the spine has the same dense character possessed by others of this species, and in other respects it is similar. The presence of the extra rows of denticles is apparently only an abnormal aberration from the type.

M. Brongniart* states that the small spine of *Pleuracanthus pulchellus*, Davis, from the cannel coal of Tingley is very nearly related to the spine of *Pleuracanthus Gaudryi*, Brong., from the Upper Coal Measures of Commentry in France; and the spine figured and described by Dr. Fritsch † as *Pleuracanthus ovalis* does not appear to differ in any essential respects. It is similar in size to *P. elegans*, Traq., and *P. pulchellus*, Davis; it has about twenty denticles on each side, and in other respects resembles the spines of immature examples of *P. leviissimus*, Ag.

* Études sur le terrain houiller de Commentry, Fauna Ichthyologique, pt. 1., p. 33. 1888.
† Fauna der Gaskohle Böhmens, vol. iii., pt. 1., p. 13, pl. xci., figs. 9, 10.
The spine of *Pleuracanthus Ælbergensis*, Fr.,* is very much like the medium-sized species of *P. levissimus*, Ag., from the Coal Measures near Glasgow. They are the same length, and each side of the spine is armed with about forty denticles. The spine of *Xenacanthus Decheni*, Goldf.,† also resembles *P. levissimus*, Ag., both in form and size, and the number of denticles in each is the same.

*Formation and Locality.*—Lowmain Coal Seam, Newsham, Northumberland; Cannel Coal, Tingley; Better-bed Coal, Yorkshire; New Ironstone (Ragmine) Fenton; Arley Mine, Burnley; Shattleston, near Glasgow.

*Ex coll.*—Museum of Natural History, Newcastle-on-Tyne; J. W. Davis, Halifax; John Ward, Longton; James Thomson, Glasgow; W. Dinning, Newcastle-on-Tyne; George Wild, Bardsley.

**Pleuracanthus robustus**, Davis.

(Pl. lxxii., figs. 10–14.)

<table>
<thead>
<tr>
<th>Species</th>
<th>Author</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
</table>

Spines: the largest examples occur at Tingley; they are imperfect, the base being absent. The part preserved is 0·09 m. in length; if perfect it would probably have measured 0·11 m. The surface is covered with fine longitudinal striations. The diameter in the median part is 0·008 m., whence it tapers to a point at the distal extremity. The basal extremity is also considerably less in diameter than the median part. An internal cavity occupies rather more than one-third the diameter at a distance of 0·09 m. from the point. The spine is very slightly curved. In section the superior surface is rounded in the upper half, and more or less triangular nearer the base; the inferior surface is slightly curved, and forms a longitudinal median ridge. The angles formed by the outer edges of this

* Op. cit., p. 15, pl. xcvii., fig. 3.
† Beit. Vorwelt Fauna, p. 23, pl. v., fig. 9, 1847; and Fritsch, op. cit., pl. xcvi., fig. 2.
surface with the sides of the spine are armed with a series of denticles. The
denticles extend from the apex a distance of 0.04 m. They are large, strongly implanted,
closely-set, recurved, and sharply pointed; about twenty on each side. The upper
surface of the denticles, i.e. the one having the greatest curvature, is produced so
as to form a miniature carina or keel, smooth and sharp (Pl. lxxii., figs. 10, 11).

Since this species was described in 1880, specimens have been found in other
localities. One of these, discovered by Mr. John Ward, in the Knowles Ironstone
Shale, at Fenton, is of peculiar interest (fig. 12). The dorsal or inferior surface is
exposed; the spine is complete, though somewhat fractured in the median part. It
is smaller than the Tingley specimens, being 0.086 m. in length. The attenuation
of the basal part of the spine, which was implanted in the integument of the fish,
is well shown. The walls are comparatively thin and hollow; they extend to
the basal extremity only on the anterior surface; the internal cavity instead of
being terminal is open a distance of 0.012 m. along the inferior surface, the walls
gradually enfolding it, as shown in the figure. The number of denticles is the same
as in the Tingley specimen.

This species has also been found in the Lowmain coal seam at Newsham,
and a specimen is figured from Mr. Atthey's collection at the Museum at Newcastle.
It is complete; 0.087 m. in length. The lateral surface is exposed, with one row
of denticles, extending a distance of 0.03 m. from the point; they are fourteen
or fifteen in number, and of a similar character to those already described
(Pl. lxxii., fig. 13).

Spines in all respects similar to the latter are found in the cannel coal at
Tingley, but of much smaller size. They appear to have belonged to fishes which
were not mature (fig. 14).

Spines belonging to the fossil fish named by Dr. Fritsch Orthacanthus pinguis,
Fr.,* bear a close relationship to this species; they are larger in size, but the robust
form and the arrangement, position, and number of the denticles resemble the
spines of *P. robustus*, Davis.

Formation and Locality.—Middle Coal Measures, Cannel Coal, Tingley,
Yorkshire; Deepmine and Knowles Ironstone Shale, Fenton and Longton,
Staffordshire; Lowmain Coal, Newsham, Northumberland; Carluke.

Ex coll.—James W. Davis, Halifax; J. Ward, Longton; Museum of Natural
History Society of Northumberland and Durham, Newcastle-on-Tyne; British
Museum (Nat. Hist.).

Pleuracanthus Wardi, Davis.

(Pl. lxxii., fig. 15.)


Spine: imperfect; the part preserved consists of the median part, 0·15 m. in length. The base and upper portion are absent. It is 0·012 m. diameter nearest the base, and diminishes gradually to 0·007 m. at the part preserved nearest to the point. The front of the spine is rounded and striated longitudinally; the posterior surface is armed with a double row of denticles, forming continuous ridges, and separated only by a narrow groove. The denticulated surface extends a distance of 0·09 m.; the denticles are short and obtuse, probably due to abrasion. The spine in transverse section is depressed on each side of the lines of denticles towards the median lateral line, which is somewhat angular. The spine is arched towards the posterior surface, and the internal cavity is large in proportion to the size of the spine.

This spine more nearly approaches the characters of Pleuracanthus cylindricus, Ag., than any other, and it has been suggested by Mr. Ward and others that its separation from that species may be conjectural. After a careful reconsideration of the specimens, however, I am still of opinion that its long slender form and decided curvature, together with the closely approximating lines of denticles forming continuous ridges, and the form of the spine in section, separate it with sufficient distinctness from the stronger cylindrical spine and the well-defined denticular arrangement of P. cylindricus.

Formation and Locality.—Ragmine Ironstone Shale, Fenton, Staffordshire.

Ex coll.—John Ward, Longton.
Pleuracanthus undulatus, sp. nov.

(Pl. lxxii., fig. 16.)

Spine: straight, 0·13 m. in length, 0·01 m. in diameter at the base, gradually diminishing to the pointed apex. Section of spine, midway and higher, circular; base somewhat crushed, but apparently oval. Upper posterior surface has two rows of denticles, which are large, broad at the base, blunt and widely separated. The denticles are placed diagonally, those of one row being slightly in advance of those of the other. At a distance of 0·03 m. from the apical extremity, the two rows are separated by a space equal to one-half the diameter of the spine, and the interval between two denticles in the same row is 0·07 m. Both the distances, between the two rows, and between the individual denticles diminish gradually towards the point.

This spine is clearly distinguished from others previously described, by the large and widely separated posterior denticulation. It was found by Mr. George Wild, of Bardsley, and presented to the Manchester Museum.

Formation and Locality.—Thin-bed Coal, Fulledge Colliery, Burnley.

Ex coll.—Mr. G. Wild: Manchester Museum, Owens College.

Pleuracanthus tenuis, Davis.

(Pl. lxxii., fig. 17.)


Spine: long and slender, imperfect; length preserved is 0·12 m.; diameter 0·005 m.; basal part circular in section; upper part more or less angular. Along each lateral margin for a distance of 0·07 m. there is a row of denticles, about eighteen or twenty in number, with bluntly-rounded points tipped with enamel. The spine is slightly curved. There is an internal canal, wide near the base, but converging higher up, and extending through the whole of the length.
This species is peculiar from its great length in proportion to the diameter. Its curved form distinguishes it from all other species, which have the denticles arranged on the directly opposing lateral surfaces of the spine.

 Formation and Locality.—Bone-bed, Better-bed Coal, Clifton, near Halifax (Lower Coal Measures).

 Ex coll.—James W. Davis.

**Pleuracanthus denticulatus, Davis.**

(Pl. lxxii., figs. 18-20.)


Spine: base wanting; length 0.055 m.; distinctly curved; lateral and anterior face smooth; circular in section; the posterior surface is flat, with two rows of denticles separated by a distance equal to one-half the diameter of the spine. The denticles are small, closely set together, broad and strongly attached at the base, contracting suddenly, and forming a carinated apex, pointing towards the base of the spine.

There are forty-five denticles on each side on the length preserved. A somewhat large central cavity extends towards the apex.

This specimen is from the Bone-bed above the Better-bed coal, and from that locality is unique; other specimens have been found in the shale above the cannel coal at Tingley, which differ little from the type; they have similar closely set strong denticles. The sides are somewhat compressed, and towards the base have slight striae. It is possible that if the base of the Bone-bed specimens were preserved, its surface might be ornamented in the same way. The lower part of the spine is thin, and the internal cavity large; the walls expanding towards the base. A perfect example would probably be 0.09 m. in length. They are composed of a dense bony substance (fig. 18).

This species differs from all the others obtained from the West Riding coal field in its arched form, and close, peculiar denticulation. **Pleuracanthus arenatus, Newberry,*** afterwards described and figured by the same author as Orthacanthus

arcuatus, Newb.,† is a spine closely allied to the one now described. It was found associated with, and buried in, an "ill-defined mass of granular material, which represents in the cannel coal the partly-ossified cartilage that composed the hard parts of the head of Diplodus. With them are also groups of Diplodus teeth still attached to the jaws." The spines were arched and tapering, and striated on the surface, and the posterior face flattened, or raised into a low ridge along the median line, and on each side of it a row of closely set acuminate depressed hooks. The hooks or denticles of the Linton species are apparently longer and more numerous than those from the Better-bed coal, but they closely resemble the Tingley specimens, especially in the striation of the surface of the spine. The Linton spines are from cannel coal.

P. denticulatus has been found in the Lowmain coal seam at Newcastle. A specimen almost perfect is 0.085 m. in length: the denticulated posterior surface extends from the apex 0.04 m., and is armed with a double row of barbs, about forty in number, on each side. The basal half of the spine is uniform in diameter, except quite near the base, which is smaller. The surface is covered with minute longitudinal striae, similar to that of the Yorkshire specimens (fig. 19).

A specimen in the collection of Mr. George Wild, from the shale above the two-feet coal at Bardsley, in Lancashire, is identical with this species. The base of the spine is not preserved, the upper portion is slightly arched backwards, and a row of denticles, about forty in number, are exposed, extending a distance of 0.05 m. from the point (fig. 20).

Formation and Locality.—Bone-bed, Better-bed Coal, Clifton and Lowmoor; and Cannel Coal, Tingley, in the West Riding of Yorkshire; Lowmain Coal, Newsham, Northumberland; Two-feet Coal, Bardsley, Lancashire.

Ex coll.—James W. Davis, Halifax; Museum of Natural History Society of Northumberland and Durham, Newcastle-on-Tyne; George Wild, Bardsley.

Pleuracanthus Howsei, sp. nov.

(Pl. lxxii., fig. 21.)

Spine: length, 0.12 m.; diameter, 0.006 m., near the base, from which the diameter gradually diminishes and terminates in a finely-pointed apex. Spine is slightly curved, more or less ovoid in section, with a double row of denticles extending along the posterior surface; from the distal extremity the denticles extend a distance of 0.05 m. The denticles are twenty-eight in each row; short,

† Palaeont. Ohio, vol. i., p. 332, pl. xl., fig. 4, 1873.
blunt, about their own diameter apart. The two rows are comparatively close together. The base of the spine is preserved; it is hollow, with thin tapering walls. The cavity appears to have been terminal. The surface of the spine is finely striated.

This spine, which it is suggested should be specifically designated *Pleuracanthus Howsei*, may be distinguished from *P. denticulatus*, Davis, to which it bears a general resemblance, by the smaller number of its denticles—it having twenty-eight, whereas *P. denticulatus* has forty-five on a spine somewhat smaller than the one now described. The denticles in this species are blunt and rounded, in the other they are long, recurved and acuminated.

**Formation and Locality.**—Lowmain Coal Seam, Newsham, Newcastle-on-Tyne.

**Ex coll.**—Museum of the Natural History Society of Northumberland and Durham, Newcastle-on-Tyne.

*Pleuracanthus alatus*, Davis.

*(Pl. lxxiii., figs. 5–13).*

Pleuracanthus alternidentatus, . . . Davis, J. W., 1880, loc. cit., p. 328, pl. xii., fig. 3.

Spine: length, 0·07 m.; breadth, 0·005 m.; straight; diameter greatest in the middle and diminishing towards each extremity, the upper one ending in a point. In section the posterior face forms a depressed curve; the anterior one is semicircular; along the angles formed by the two there extends, for about one-third the length from the apex, a double row of denticles, varying in number from seven to ten on each side. The denticles are broad at the base, connected one to another
I.—Pleuracanthidæ.

laterally, short, and terminating obtusely, with an elongated cutting edge parallel to the longitudinal axis. They diminish in size towards the point, and for about 0·004 m, the point of the spine is free. The surface of the spine is uniformly covered by minute longitudinal striae. In most of the examples the base of the spine is crushed; its walls are thin, and the internal cavity comparatively large.

The specimen described as Pleuracanthus alternidentatus, Davis,* from Middleton, near Leeds, probably belongs to this species. It is slightly more robust and longer, and the spine in section is rounder; the principal difference is in the more widely separated position of the denticles and their being placed along the margins in alternate series, instead of being opposite. Since the description was written in 1881 other specimens have been found in Yorkshire and also in Staffordshire. The latter are particularly interesting because they appear to indicate a passage between the two forms; the number of denticles is smaller than those of the type specimen of P. alatus, but greater than those of P. alternidentatus, and they are placed somewhat irregularly. Taking into consideration the new evidence it appears desirable to regard the two forms as one species, and it is now suggested that Pleuracanthus alternidentatus be included as a synonym of Pleuracanthus alatus, Davis.

A small specimen from the Deepmine shale at Longton, in Staffordshire, from the collection of Mr. John Ward, is 0·017 m. in length; one half the length is armed with a double row of barbs, numbering seven or eight on each side. The characters of this example appear to indicate its relationship to P. alatus, and it is probably the spine of an immature fish. It is worthy of note, however, that the denticulated surface bears a much larger proportion to the whole length of the spine than in the fully grown specimens, and the distal extremity is not so pointed (Pl. lxxiii., figs. 7–9).

Examples of spines found in the Lowmain coal of Newsham occur in the Atthey collection at the Newcastle Museum. They have a length of 0·045 m. A double row of denticles extends a distance of 0·017 m., as in the type specimen, each row containing sixteen to eighteen denticles, longer, recurved, and more pointed than in the specimens from Tingley or Staffordshire. These characteristics vary considerably from the original; but the general resemblance of the form is sufficiently close to justify its inclusion. The basal extremity of the specimen figured is well exposed (Pl. lxxiii., figs. 10, 11).

Mr. James Thomson has furnished examples collected at Newarthill, Quarter Hamilton, and other localities near Glasgow, which have about ten denticles in each row, and approach very near to the type from Tingley (Pl. lxxiii., fig. 13).

Formation and Locality.—Middle Coal Measures; Cannel Coal, Tingley and Middleton, near Leeds; Knowles Ironstone Shale, Fenton; and Deepmine Ironstone,
Longton, Staffordshire; Watston; Stonehouse; Newarthill; Quarter Hamilton, Scotland; Lowmain Coal Seam, Newsham, Newcastle-on-Tyne.

Ex coll.—James W. Davis, Halifax; Museum Literary and Philosophical Society, Leeds; John Ward, Longton; James Thomson, Glasgow; Atthey Collection, Museum Natural Hist., Newcastle-on-Tyne.

**Pleuracanthus erectus**, Davis.

(Pl. lxxiii., fig. 14-16.)


Spine: length, 0·09 m.; breadth at the base, 0·008 m., whence the sides converge in straight lines to an elongated and acute point; antero-posteriorly compressed; section oval, lateral margins produced, forming a series of convex, compressed projections. The projections have a broad base and are widely separated from each other. The surface of the spine is striated longitudinally.

Since the description of the original specimen from the cannel coal at Tingley, other specimens have been obtained from the same locality, which prove conclusively that the similarity to *Pleuracanthus lavissimus*, Ag., indicated in the original description,* and since emphasized by other authors,† was only a generic one. The species are quite distinct, and may be distinguished by the form and character of the denticles very readily. In this species they are broad at the base and more or less rounded, whilst in *P. lavissimus* they are long, recurved, and sharply pointed. The denticulated margin of the spine in the type specimen is 0·055 m. in length, and on this margin there are twenty-two denticles; in a specimen of *Pleuracanthus lavissimus*, Ag., from the Lowmain coal, of a similar size and with the same length of denticulated margin, there are thirty-seven denticles. This comparative paucity of denticles in *P. erectus* is characteristic of all the specimens which have come under observation. In shorter spines, which it is presumed were those of younger fishes, the disparity is still more marked, and it is equally borne out by larger ones. A very fine example (Pl. lxxiii., fig. 14), which is preserved, along with others, from the Lowmain coal seam, in the Atthey collection, may be compared with the specimen of *Pleuracanthus lavissimus*, Ag. (Pl. lxxii., fig. 1), from the same bed. In the latter there are sixty-five denticles on each margin,

extending over 0.13 m.: on each margin of the *Pleuracanthus erectus* there are only forty-five denticles, and they occupy exactly the same area as the others.

The example last referred to has a length of 0.22 m.; at a distance of 0.07 from the basal extremity the lateral diameter of the spine is 0.012 m., and thence it gradually diminishes to an attenuated point at the distal end, and towards the base the diameter is also reduced. The spine is oval in section, compressed antero-posteriorly; its walls are comparatively thin at the basal end. The internal pulp cavity appears to have been terminal.

A spine of *P. erectus*, having a length of 0.21 m., has been found in the shale immediately above the two-feet coal at Bardsley. Other specimens, not so perfectly preserved, have been found, and associated with them examples of *P. levissimus*, Ag. The denticulated margin of the specimen first referred to occupies 0.11 m., rather more than one-half the length of the spine; the number of denticles is thirty-one on each side. A comparison of the more or less fragmentary spines of the two species exhibits very clearly the difference in denticulation which has been observed in those from other localities.

**Formation and Locality.**—Cannel Coal, Middle Coal Measures, Tingley; Lowmain Coal Seam, Newsham; Two-feet Coal Seam, Bardsley.

**Ex coll.**—James W. Davis, Halifax; Museum of Natural History Society, Newcastle-on-Tyne; George Wild, Bardsley.

**Pleuracanthus horridulus**, Traquair.

(Pl. lxxii., figs. 22, 23.)


Length of spine, 1 inch; diameter at base, $\frac{1}{12}$ inch; gently arched, tapering to a point, lower part striated, upper smooth; upper third of posterior surface set with a double row of large recurved denticles, eight or nine on each side, placed alternately with each other.

The specimens referred to were described by Dr. Traquair without figures, and I have not the originals for reference; other specimens of this species from
Borough Lee have, however, been accessible, and I have before me an example from the Bone-bed above the Better-bed coal at Clifton, which corresponds exactly with the Borough Lee specimens. The spine is imperfect, the distal portion only being preserved; it is 0'015 in length, and there are eight or nine large recurved, sharply-pointed denticles; the surface of the spine is smooth. Except that the denticles are larger, the spine agrees with the smaller examples of Pleuracanthus alatus, Davis, and it is quite probable that additional specimens may show a gradation of the one into the other; for the present it is suggested that the specimens should be considered as a separate species.

**Formation and Locality.**—Bone-bed, Better-bed Coal, Clifton, Yorkshire.

**Ex coll.**—James W. Davis.

**Pleuracanthus cylindricus** (Agassiz), Davis.

(Pl. lxxiii., figs. 1–4.)


Spine: erect and straight, or with a very slight curvature; attains a large size. A specimen in the collection of Mr. Ward, from the Fenton Ironstone shales, was probably not less than 0'55 m.; the base is imperfect, but the part preserved, probably the thickest, has a diameter of 0'025 m. A more perfect specimen has a length of 0'31 m., and a diameter of 0'018 m., at a distance of 0'2 m. from the apex; from this part the diameter of the spine gradually decreases upwards and ends in
I._—Pleuracanthidae.

741

an acuminate apex. In section the spine is more or less round, except at the base, which is compressed antero-posteriorly; the extremity is slightly tapering and rounded. The internal cavity is not terminal, but is open along the posterior surface for a distance of about 0'04 m. The orifice is large and the walls thin at the base; higher, the cavity is reduced to one-third the diameter of the spine, and gradually diminishes towards the apex. The surface of the spine is covered with longitudinal striations which sometimes disappear towards the apex. On the posterior surface is a double row of closely approximating denticles; they extend over one-half the length of the spine, and number seventy or eighty denticles on each side; they increase in size with the diameter of the spine or towards the base. The denticles are round near their base, contracting to an obtuse point, directed diagonally towards the base, and at the same time away from the centre, of the spine (fig. 1).

A magnificent specimen of the spine of this species is preserved in the British Museum (Nat. Hist.). It forms a part of the Egerton collection, but unfortunately there is no record of the locality from which it has been obtained. The matrix is a hard ironstone shale, and there are a number of molluscan remains on the slab, *Goniatites, Pecten*, and other marine forms, together with the remains of a plant, apparently *Lepidostrobus*. The spine is 0'39 m. in length, and the base is imperfect. Its greatest diameter is 0'018 m. The spine has a slight, graceful curvature, with smooth surface somewhat deeply striated longitudinally. The denticulated surface extends 0'18 m. along the posterior surface, and on each row there are fifty denticles. Those situated on the upper part are long recurved hooks, each separated from the next by a distance equal to the diameter of its own base. Midway along the denticulated surface the denticles are larger, thicker, and stronger; at the lower part they diminish again in size and are shorter and more stumpy, where not broken off in the opposing matrix of the opposite slab. (Pl. LXXXIII., fig. 2).

The largest examples of this species are from the Fenton and Knowles Ironstone shales of North Staffordshire. The specimens from the Scotch Measures are smaller, and some of them, as, for example, one from Quarter Hamilton (fig. 4), in the collection of Mr. James Thomson, of Glasgow, has the rows of posterior denticles situated wider apart than those described, the intervening area being quite convex, whilst in those from Staffordshire it is flat or slightly concave (fig. 3).

The spine of *Orthacanthus bohemicus*, Fr., from the gas-coal of Nyran, in Bohemia, probably occupies a position closely allied to this species.

*Formation and Locality.*—Shale above the Ragmine Ironstone, Fenton; Knowles and Chalky-mine Ironstones, Longton; and Brown-mine Ironstone, Silverdale, in Staffordshire; Quarter Hamilton, Scotland.

*Ex coll.*.—John Ward, Longton; James Thomson, Glasgow; Egerton Collection, Natural History Department, British Museum.
Pleuracanthus Thomsoni, sp. nov.

(Pl. lxxiii., fig. 17.)

Spine: distal extremity absent; length preserved 0·8 m.; greatest diameter 0·06 m.; section circular, with round internal cavity. If perfect the spine would probably be 0·9 m. in length. The denticulated surface which is preserved occupies 0·18 m., and consists of a double row of eleven denticles separated by a distance of rather more than 0·02 m.; the intervening space is occupied by a ridge. The denticles are broad and obtuse, with a broad lateral depression between each. The spine is slightly curved.

This species approaches most nearly to P. robustus, Davis, in general appearance. It differs in being thinner in proportion to its length. The denticulated surface is shorter, and the two rows are closer together. In P. robustus, the denticles extend over half the length of the spine; in this one they cover little more than one-fourth. The denticles themselves are short and rounded, whilst in the former they are closely implanted, recurved, pointed, and extend from the surface a distance equal to one-half the diameter of the spine.

Formation and Locality.—Above the soft coal in the Red Sandstones at Quarter Hamilton, Kilmarnock.

Ex coll.—James Thomson, Glasgow.

Pleuracanthus obtusus, nom. nov.

(Pl. lxxiii., fig. 18.)


Spine: length 0·105 m.; greatest diameter 0·007 m. The spine is gently arched backwards, the exposed part covered with minute longitudinal striations. In section the spine is circular: from the apex extending 0·05 m. along the posterior surface, there is a right and left row of seven widely separated protuberances or denticles. In the lower part there is a distance of 0·007 m. between the apex of two consecutive denticles; they are broad longitudinally, laterally compressed, and rapidly converge to a rounded obtuse apex. The denticles are alternate, the projection on one side being opposite to the depression on the other; an internal
cavity, circular in form, extends upwards from the base. The walls of the cavity forming the base of the spine are thin, and in the specimen now described, they are crushed.

Mr. A. Smith Woodward* doubtfully places *Pleuracanthus biserialis* as a synonym of *Pleuracanthus cylindricus*, Ag. There is, however, a great difference between the two spines. The greatest discrepancy is in the form of the denticles ranged on either side of the dorsal aspect of the spine. In *Pleuracanthus (Orthacanthus) cylindricus*, Ag.; the teeth are more or less hooked, pointed, and close together; but, in this instance, the denticles are widely separated, rounded, and blunt; to such an extent is this the case that the term is scarcely applicable; they have more of the character of wavy projections alternately produced; first right, then left, from the dorsal surface of the spine; and it was in consideration of this peculiarity that the name was chosen. Even if the spine were worn or abraded, which does not appear to be the case, the great difference in the number of the denticles must distinguish it from *P. cylindricus*, Ag., which has six or seven times as many denticles as the spine now described.

In the original description† of the specimens forming this species attention was drawn to their resemblance to *Orthacanthus*, the principal points of difference being in the curved contour of the spine, and in the peculiar form and large size of the posterior denticles. During the following year a number of additional specimens were discovered forming intermediate stages between *Pleuracanthus* and *Orthacanthus* which led to a suggestion that the two genera should be combined along with *Xenacanthus* and *Diplodus;‡* and all form only one genus. After considerable care in comparing specimens, it appears probable that *Phricacanthus* must be included in the genus *Pleuracanthus*. The latter now includes not only the straight spines of *Orthacanthus* type, but also the curved spines, since allocated to the genus, and so covers one of the characteristic features of *Phricacanthus*; and the denticles which are now known to be extremely varied in that genus may well embrace the double row of large, widely separated and alternate denticles of *Phricacanthus*. The specific name *biserialis* is pre-occupied, having been applied to a species of *Pleuracanthus* from the Coal Measures of Ohio by Dr. J. S. Newberry§ in 1856. It is now proposed to distinguish the species as *Pleuracanthus obtusus*, Davis.

**Formation and locality.**—Bone-bed above Better-bed Coal; Clifton, Yorkshire.

**Ex coll.**—James W. Davis, Halifax.

---

Pleuracanthus serratus, sp. nov.

(Pl. lxxiii., figs. 19, 20.)

Spine: length averages 0·04; the longest example is 0·07, and the shortest 0·015. An example 0·04 in length is 0·002 in diameter at the base, and diminishes to a fine point at the distal extremity. The anterior surface is more or less circular in a section cut across the spine; the posterior surface is also rounded but to a smaller extent. A double row of denticles, twenty in number on each side, extends along the lateral posterior surface in the position shown in fig. 19. The denticulated surface extends from the point a distance of 0·025 m. towards the base. The denticles present the appearance of a series of triangular pendants, the point of each being suspended from the base of the preceding one; they are closely set, and the base, at its lowest and widest part, is equal in width to the height of the apex of the wedge-shaped denticle. The denticles are largest midway, and decrease in size both towards the distal and basal extremities.

A considerable number of these small spines have been obtained from the Lowmain Coal Seam. The posterior position of the denticles at once distinguishes them from small examples of Pleuracanthus lavissimus, Ag., which frequently occur in the same beds about the same size. The number of denticles is equal to that of P. robustus when full grown, but their form is sufficiently distinctive, and they do not fall in with any of the previously described species.

Formation and Locality.—Lowmain Coal Seam, Newsham.

Ex coll.—Atthey Collection, Museum of the Natural History Society of Northumberland and Durham at Newcastle-on-Tyne.

Pleuracanthus Woodwardi, sp. nov.

(Pl. lxxiii., fig. 21.)

Spine: length 0·25 m.; point and base imperfect; probably 0·025 must be added at distal end, equal to 0·275 m. without addition to base, or 0·3 in length if complete; base crushed; at a distance of 0·1 m. from proximal extremity the diameter is 0·015 m., from which point it tapers to the distal end. In section the spine is oval, with a flattened anterior surface. The posterior surface has a slight median ridge, and on each side, extending a distance of 0·1 m. on the part preserved (or probably 0·12 m. if it were perfect), there is a row of large,
recurved, acuminate denticles, forty-five in number. The surface of the spine is smooth or slightly striated.

This species is most nearly related to *P. lavissimus*, Ag., but the position of the denticular row is not lateral but is placed far towards the posterior surface as shown in fig. 21 a; the denticles are more hooked than in *P. lavissimus*.

The rows of denticles are, however, not nearly so closely approximated as in *P. cylindricus*; they appear to show a connecting and intermediate link between the two species, and go a long way to prove their generic identity. I have appended the specific name *Woodwardi* in recognition of the services of my friend Mr. A. Smith Woodward.

**Formation and Locality.**—Coal Shale, Dalkeith. Candenfoot, Dalkeith.

**Ex coll.**—No. P 3178a. Enniskillen Collection, Natural History Department, British Museum. No. P 1730. Egerton Collection, Natural History Department, British Museum.

**Pleuracanthus (Lophacanthus) Taylori**, Stock.

(Pl. lxxiii., figs. 22, 23.)

A spine from Airdrie (No. 42,035 in B. M. Coll.), perfect at the proximal end, but wanting the distal one, is 0·20 m. in length. It is slightly curved, 0·01 m. in diameter at the widest part, more or less circular in section, the antero-posterior diameter being greater than that between the sides, with a double row of denticles extending along the posterior surface to a distance of 0·07 m. of the base. The denticles are short, rather widely separated, slightly curved backwards. The rows of denticles are separated by a distance equal to half the diameter of the spine between the anterior and posterior surfaces. The surface is smooth or slightly ridged in wavy lines. The proximal extremity is rounded with the terminal orifice open for a short distance along the posterior surface. The internal cavity higher in the spine is small.

This spine closely resembles that of *P. cylindricus*, Ag., but has a more distinct curvature than the spine of that species, and is more especially distinguished by the wide area separating the two rows of posterior denticles.

The spine, No. P 42,035, appears to be closely related to a spine from the Lowmain Coal Seam at Newcastle, at present in the Atthey collection in the Museum of Natural History. The Newcastle specimen is 0·24 m. in length, and is slightly thicker than the one in the British Museum, but in other respects is characterized by its curved outline and the position of the two rows of denticles (fig. 23).
The spine described by Mr. Thomas Stock* as *Lophaeanthus Taylori* was from the Lowmain Coal Seam. The writer has not had an opportunity to inspect the original, but the woodcut with which the description is illustrated indicates a close resemblance to the spine in the Atthey collection. The section as illustrated by the woodcut, is different, but that may be perhaps accounted for by the imperfection of the specimen. The relationship between these spines being so close, I feel justified in including them under the specific name given by Mr. Stock; but as I am convinced that they are not generically distinguishable from the spines of *Pleuracanthus*, they must be included in that genus.

*Formation and Locality.*—Coal Measures, Airdrie; Lowmain Coal Seam, Newsham.

*Ex coll.*—Natural History Department, British Museum; Mr. Joseph Taylor, of Shire Moor; Museum of Natural History, Newcastle.

**Pleuracanthus (Compsacanthus) triangularis** Davis.

(Pl. lxxiii., fig. 24.)


Spine: straight, robust, upper part perfect; base somewhat crushed; 0.063 m. in length; greatest diameter 0.005 m. midway between the extremities; distally it gradually contracts, and ends in a point. The base is hollow, and the walls are thin; the internal cavity apparently terminal. The lateral surfaces of the spine are compressed anteriorly, which gives it a triangular form in section. The posterior surface, from which springs a single median row of denticles, is rounded. The denticles are broad at the base, compressed laterally, ending in an obtuse point.

This spine, which still remains unique, was found in the Cannel Coal of Tingley; it was included in Dr. Newberry’s genus *Compsacanthus*,† characterized by having only a single row of denticles on the posterior surface of the spine. *Compsacanthus levis*, Newb., is circular in section, and there are a considerable number of denticles diminishing in size from the lower towards the upper part of the spine. In this species the number of denticles is small, and the spine is more or less triangular in section.

Dr. Zittel has expressed the opinion that probably *Compsacanthus* will be

---

found identical with Orthacanthus,* and Mr. A. Smith Woodward accepts the same view in cataloguing the fossil-fishes in the British Museum, and places the genus as a synonym of Pleuracanthus.†

Formation and Locality.—Middle Coal Measures, Tingley, in Yorkshire.

Ex coll.—James W. Davis, Halifax.

Pleuracanthus (Diplodus) equilateralis, Ward.

(Pl. lxxiii., fig. 27.)


Teeth: "Base of tooth relatively small, rounded, or oval; concave below, coarsely pitted with a strong prominent knob or heel-like projection at the anterior margin. Lateral denticles, two in number, divergent on the same plane; they are short, conical, broad for nearly their entire length, when they rapidly contract; compressed, equal in length, with their margins finely carinated. Between the two lateral denticles, at their basal junction, there is a slightly elevated boss, from which spring two intermediate denticles, equal in length, compressed, with smooth margins" (Ward).

Formation and Locality.—Shale overlying the Deepmine Ironstone, Longton, Staffordshire.

Ex coll.—John Ward, Longton.

Genus, Anodontacanthus, Davis.


The spines included in this genus are straight, more or less tapering to a point. Internal cavity large, terminating at the base without posterior extension of the opening. Distinguished from Pleuracanthus by the absence of denticles.

* Handb. der Paläontologie, vol. iii., pt. i., p. 90. 1887.
† Cat. Foss. Fishes, pt. i., p. 2.
The genus is confined to two species from the Cannel Coal of Tingley, in Yorkshire. A single specimen described as a third species, *A. fastigiatus,* from the Blackband Ironstone at Loanhead, in the Carboniferous Limestone series, near Edinburgh, is considered by Dr. Traquair, who has other specimens, to belong to another genus, and awaits his further elucidation.

**Anodontacanthus acutus**, Davis.

(Pl. lxxiii., fig. 25.)


Spine: length, 0·6 m.; breadth, 0·05 m., gradually tapering to a point; straight, circular in section, with an internal cavity occupying one-half the diameter of the spine in the middle of its length; towards the base the walls become thinner; orifice terminal. There are no lateral denticles.

*Formation and Locality.*—Cannel Coal, Tingley.

*Ex coll.*—James W. Davis, Halifax.

**Anodontacanthus obtusus**, Davis.

(Pl. lxxiii., fig. 26.)


Spine: larger than the preceding one, probably 0·9 m. in length and proportionately thick; oval in section, with the internal cavity much smaller than in *A. acutus*; distal extremity obtusely flattened and circular.

*Formation and Locality.*—Cannel Coal, Tingley.

*Ex coll.*—James W. Davis, Halifax.

PLATE LXV.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—1. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXV.

Pleuracanthus (Diplodus) larissimus, Agass.

Figure

1. Lower jaws in natural position; reduced to half diameter.
   
   a. Right lower jaw, under surface. Posterior portion of jaw, apparently divided by centres of ossification into a series of plates.
   
   b.b. Left lower jaw. Outer margin of the two mandibles thickened by the pressure from the other side of the upper jaws.
   
   c.c. Terminal ossifications forming the snout, and extending between the anterior extremities of the palato-quadrates.
   
   d. Plate from the left posterior margin of the cranium.
   
   e.e. Cranial plates, probably located anteriorly to d.

2. Pectoral fin (natural size).

3–15. Teeth from various parts of the jaws (natural size).

Formation and Locality.—1, 3–15, Low Main Coal Seam, Newsham, Northumberland; 2. Cannel Coal, Tingley.

Ex coll.—Atthey Collection, Museum, Newcastle-on-Tyne; James W. Davis, Chevinedge, Halifax.
PLATE LXVI.

ON THE FOSSIL FISH-REMAINS OF THE COAL MESSAGES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXVI.

_Pleuracanthus_ (Diplodus) larissimus, Agass.

Figure

1. Upper jaws (palato-quadrates). Opposite side of specimen represented on Plate LXV. Reduced to half diameter.

   a. Right upper jaw.

   b. Left upper jaw; each with wide lateral expansion, forming osseous plates, joining along the median line of the palate.

   c. Anterior extremities of palato-quadrates, to which were attached the bones of the snout (Pl. LXV., c.c.).

   d. Inferior surface of cranial plate exhibited on Pl. LXV.

   e.e. Inferior surface of plates indicated by same letter on Pl. LXV.

_Formation and Locality._—Low Main Coal Seam, Newsham.

_Ex coll._—Atthey Collection, Museum, Newcastle-on-Tyne.
PLATE LXVII.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXVII.

*Pleuracanthus* (? species).

(Natural size.)

Figure 1. Shoulder girdle, with parts of the branchial arches.
   a. Left scapular arch.
   b. Right scapular arch.
   c. Left branchial arches.
   c.1. . . .
   c.2. . . .
   c.3. . . .
   c.4. . . .
   d. Right branchial arches.
   d.1. . . .
   d.2. . . .
   d.3. . . .
   e. Hyomandibular bone.
   f. ? Base of attachment for the spine.
   g. Gill-rakers (stemmatoid ossicles) derived from the gill-arches.

*Formation and Locality.*—Low Main Coal Seam, Newsham, Northumberland.

*Ex coll.*—Atthey Collection, Museum, Newcastle-on-Tyne.

2. Bones of upper surface of the cranium.
   a. Parieto-frontal plates.
   b. Occipital.
   c. Lateral occipitals.
   d. Postero-lateral plates, completing the posterior margin of the cranium.
   e. f. Intermediate plates between the parieto-frontals and the lateral plates, g. h.
   g. h. Lateral plates; g. on the left side in fig. 2 is covered by the displaced plate d.
   i. Anterior plates over the snout.
   j. Small median hexagonal plate.
   or. Orbits.

2a. Restoration of No. 2. The letters above apply to this figure.

8. Underside of the occipital plate.

*Formation and Locality.*—Low Main Coal Seam, Newsham, Northumberland.

*Ex coll.*—William Dinning, Newcastle-on-Tyne.
PLATE LXVIII.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXVIII.

_Pleuracanthus_ (? species).

(All figures natural size.)

Figure

1. Right lower jaw. Internal surface.
1a. " " " External surface.
2. Articulating extremity of lower jaw.
3. The same of another specimen.
   a. Articulating process.
   b. Angular bone.
   c. Dentary bone.
4. _Pleuracanthus (Diplodus) levissimus_, Agass. Exhibiting the serial arrangement of the teeth.
   a. Teeth of upper jaw.
   b. Teeth of lower jaw.
5, 5a. Osseous fragment, with articulating surface.
6. Another example, with articulating extremity.
7. Osseous plate.
8. Occipital plate.
9. Pterygopodium (clasper) of the ventral fin.
   a. Clasper.
10. Pterygopodium, (?).

Formation and Locality.—All except fig. 4 from Low Main Coal Seam, Newsham. Fig. 4, Thin Bed Coal, Burnley, Lancashire.

Ex coll.—Figs. 1, 2, 5, 6, 7, 8, 9, W. Dinning, Newcastle-on-Tyne; fig. 3, Atthey Collection, Museum, Newcastle-on-Tyne; fig. 4, George Wild, Bardsley, Lancashire.
PLATE LXIX.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXIX.

Pleuracanthus (Diplodus) lavissimus, Agass.

(Reduced to half diameter.)

a. Right ramus of lower jaw.

a'. Articulatory surface.

b. Anterior extremity of left ramus of lower jaw.

c. Dentary surface, with teeth.

d. Extremity of the palato-quadrate.

e. \{ l., n., m., iv. \} Bones of the branchial arches.

f. g. Detached gill-rakers.

Formation and Locality.—Low Main Coal Seam, Newsham, Northumberland.

Ex coll.—Atthey Collection, Museum, Newcastle-on-Tyne,
ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXX.

Pleuracanthus (Diplodus) livissimus, Agass.

Figure

1. Head considerably crushed, with spine (natural size).
   a. Right ramus of lower jaw, showing arrangement of teeth in situ.
   b. Lower jaw; left ramus.
   c. ? Hyomandibular.
   d. d. Cranial plates.
   e. Spine.

2-9. Examples of so-called "Stemmatodus" (enlarged).

Formation and Locality.—Low Main Coal Seam, Newsham, Northumberland.

Ex coll.—Atthey Collection, Museum of Natural History, Newcastle-on-Tyne.
PLATE LXXI.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXXI.

Figure

1. *Pleuracanthus* (Diplodus) *latisimus*, Agass., exhibiting the posterior part of the head, together with spinous bones of the hæmal or neural arches, and inter-spinous bones. (Reduced to half diameter.)

   a. Lower jaw.
   b. Cranial plates dissociated.
   c. Vertebral spines (? neural), with enlarged base.
   d. Inter-spinous rays.
   e. Surapophysial ray.
   t. Teeth.

2. Inter-spinous ray. Natural size.

3. 

4. Surapophysial ray.

5. Teeth. Enlarged.

*Formation and Locality.*—Low Main Coal Seam, Newsham, Northumberland.

*Ex coll.*—William Dinning, Newcastle.
PLATE LXXII.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—1. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXXII.

Figure


2. Cannel Coal, Tingley. *Ex coll.—James W. Davis.*
6, 7. Shattleston, Glasgow. *Ex coll.—James Thomson.*


N.B.—Fig. 2 in this Plate has been drawn by mistake instead of the specimen of *P. levisissimus*, referred to in the text.

[16]
PLATE LXXIII.

ON THE FOSSIL FISH-REMAINS OF THE COAL MEASURES OF THE BRITISH ISLANDS.—I. PLEURACANTHIDÆ.
EXPLANATION OF PLATE LXXIII.

Figure

1-4. Pleuracanthus cylindricus (Agassiz), Davis.

2. ? *Ex coll.*—P. 1735, British (Natural History) Museum.

5-13. Pleuracanthus alatus, Davis.

5. Tingley, Yorkshire. *Ex coll.*—James W. Davis.

14-16. Pleuracanthus erectus, Davis.


22, 23. Pleuracanthus Taylori (Stock), Davis.


[18]
TRANSACTIONS (NEW SERIES).

Vol. II.—Parts 1–2.—August, 1879, to April, 1882.
Vol. III.—Parts 1–14.—September, 1888, to November, 1887.

VOLUME IV.


3. Observations of the Planet Jupiter, made with the Reflector of Three Feet Aperture, at Birr Castle Observatory, Parsonstown. By Otto Boeddicker, Ph.D. Plates XXIV. to XXX. (March, 1889.) 3s.


5. A Revision of the British Actiniae. Part I. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin. Plates XXXI. to XXXVII. (June, 1889.) 5s.


7. Survey of Fishing Grounds, West Coast of Ireland, 1890. I.—On the Eggs and Larvae of Teleosteans. By Ernest W. L. Holt, St. Andrew’s Marine Laboratory. Plates XLVII. to LII. (February, 1891.) 4s. 6d.


10. The Slugs of Ireland. By R. F. Scharff, Ph.D., B.Sc., Keeper of the Natural History Museum, Dublin. Plates LVI., LVII. (July, 1891.) 3s.


12. A Revision of the British Actinia. Part II.: The Zoanthæ. By Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and Miss Alice M. Shackleton, B.A. Plates LVIII., LIX., LX. (November, 1891.) 3s. 6d.

13. Reports on the Zoological Collections made in Torres Straits by Professor A. C. Haddon, 1888–1889. Actinæ: I. Zoanthæ. By Professor Alfred C. Haddon, M.A. (Cantab.), M.R.I.A., Professor of Zoology, Royal College of Science, Dublin; and Miss Alice M. Shackleton, B.A. Plates LX., LXI., LXII., LXIII., LXIV. (December 1891.) 3s.


[Title-page and Contents to Volume IV., Series II.]